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## PITCH PERCEPTION IN CHANGING HARMONY

# PITCH PERCEPTION IN CHANGING HARMONY

A thesis submitted in partial fulfillment  
of the requirements for the degree of  
Master of Music in Music

By

Cecilia Taher  
University of Iowa  
Doctorate of Musical Arts, 2009

May 2012  
University of Arkansas

## ABSTRACT

The role of harmony in the definition of tonality provides theoretical framework for the hypothesis that harmonic context affects pitch perception. In tonal music, the stability of individual notes depends on the harmonic setting. It seems then reasonable to expect harmonically guided variations in the cognitive representation of tones. With the purpose of enhancing current models of pitch perception, this thesis proposes an empirical investigation of the effects of harmony on pitch sensitivity. In two experiments, nonmusicians performed a same/different discrimination task on two pitches (a reference tone RT and a comparison tone CT) that were embedded in a melody with a clearly implied harmony. Visual cues facilitated the identification of the tones. The main experiment included only stimuli with different harmonic contexts for RT and CT. It consisted of a repeated-measures design with two bi-level factors, pitch (RT=CT and RT $\neq$ CT) and harmonic stability (equal and unequal stability for CT with respect to RT). By considering only changing-harmony stimuli, this study greatly minimized effects of potential confounds, allowing a comparative examination of the perception of equal versus different pitches. An ANOVA with percent correct as dependent variable and  $c$  (response-bias measure) as covariate revealed greater disruption in discrimination of different than identical notes; better pitch sensitivity in unequal than equal harmonic-stability situations; and increased perception abilities for unequally, with respect to equally, stable notes that differed in pitch, but the opposite effect for equal tones. The second experiment consisted of a between-subjects design with two factors, harmony (changing and nonchanging) and pitch (as above). An ANOVA showed better pitch discrimination abilities ( $d'$ ) under nonchanging than changing harmonic contexts in common musical situations. Altogether, the findings suggest that changing harmonic settings tend to bring together the percepts of pitches that are introduced in

adjacent chordal functions, particularly when the tones are stable members of their contextual harmony. This thesis contributes to the field of music cognition by illuminating our understanding of the perceptual mechanisms involved in the interaction of pitch and harmony, proposing an alternative methodological approach, and emphasizing the problems that underlie the study of contextual aspects of music.

This thesis is approved for recommendation  
to the Graduate Council.

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## CHAPTER 1

### Statement of the Problem

Over seventy years of research have shown that both psychoacoustic (bottom-up) and cognitive (top-down) processes are involved in the perception of musical pitch (for a review see Cross, 2007; Plack & Oxenham, 2005). The perceptual dimension of pitch arises from experience and musical contextualization of frequency spectrums (acoustic signals). Because perception is shaped by experience, the neural processes involved in decoding frequency patterns that are necessary for hearing (and interpreting) pitches must entail the construction of internal, personal representations of those patterns. Musical context, which can be both objectively defined (from the point of view that it can be empirically manipulated) and subjectively interpreted (from the point of view that it is culturally shaped, leading different listeners to create diverse expectations), plays an essential role in shaping our perception of acoustic stimuli.

Psychoacoustic studies have shown fundamental differences between acoustic phenomena and perceived sounds (for a review, see Yost, 2009). The phenomenon of the missing fundamental, the perception of the pitch of a tone when its fundamental frequency ( $F_0$ ) is not physically present, provides a clear example (Yost, Popper, & Fay, 1993). Our mental representation of a given pitch results from both acoustic properties and cognitive processes. Furthermore, cognitive processes become more involved than psychoacoustic processes in shaping the perception of tones that are spectrally more complex (Yeary, 2011).

Numerous empirical and theoretical studies have provided substantial evidence towards the development of models of pitch perception. Research in cognitive sciences has revealed that our perception of pitches and chords is highly dependent on the tonal context (e.g., Bigand, Madurell, Tillmann, & Pineau, 1999; Gorfein, 1989; Holleran, Jones, & Butler, 1995; Huron, 2006; Krumhansl, 1990; Patel, 2008; Plack et al., 2005). We can hear the same note or chord

differently, depending on the tonal context in which it is presented. Similarly, we perceive different notes as equal in certain situations.<sup>1</sup> Furthermore, it is the tonal context what determines many aspects of pitch perception in music. The way a fixed collection of pitches is arranged has implications in our perception of the key (Butler, 1989), and our tonal interpretation of a succession of pitches is shaped by the harmonic context (Temperley, 2001). Finally, within the neuroscience literature, evidence has shown that the musical context in which notes or chords are presented influences neural patterns in the brain (e.g., Janata, Birk, Van Horn, Leman, Tillmann, & Bharucha, 2002; Koelsch, Gunter, & Friederici, 2000; Koelsch, Jentschke, Sammler, & Mietchen, 2007; Patel, Gibson, Ratner, Besson, Holcomb, 1998; Regnault, Bigand, & Besson, 2001). For instance, the same chord introduced in different tonal settings produces different patterns of neural activity (Regnault et al., 2001).

Krumhansl's probe tone studies have provided the foundation for research in pitch perception. The fundamentals of her work are summarized in his book *Cognitive Foundations of Musical Pitch* (1990). It is now well known that, when we hear pitches within a tonal context, we perceive them according to a key-centered hierarchy. In accordance with traditional music theory, experimental research in music perception has shown that some tones and chords fit a key better than others (e.g., Brown, Butler, & Jones, 1994; Krumhansl, 1990; Krumhansl & Kessler, 1982). For instance, the tonic note and tonic chord receive the highest fitting rates among all notes and chords respectively. In a similar manner, empirical evidence supports that, within a tonal context, we perceive certain succession of pitches (scale degrees) or chords as more suitable (within a particular key) than others (Krumhansl, 1990, 1979). As a result of her

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<sup>1</sup> In the context of this thesis, the terms equal and same are used indistinctively (e.g., two equal notes are two instances of the same pitch).

research, Krumhansl proposes the *principle of contextual distance* (Krumhansl, 1990, p. 196) to conceptualize the perceptual distance between two pitch classes or chords:

“The average distance between two elements varies inversely with the extent that the elements are stable or play significant functions in the context key.”

The evidence presented above suggests that a “key-centered force” or “*tonal attraction*”<sup>2</sup> plays an important role in the way we listen to, perceive, and comprehend tonal music. This idea finds support not only in the cognitive field but also in the psychoacoustic domain. For instance, Cook (2009) proposes an acoustical explanation for the perception of harmony in diatonic music that includes aspects of triadic tension, stability and dissonance. Similarly, several studies have found that the degree of consonance of musical intervals, which in turn affects tonal attraction, is contained in the acoustic signal (Parncutt, 1989; Plomp & Levelt, 1965; Sethares, 1999). Furthermore, Woolhouse’s theory of interval cycles provides psychoacoustical support for the idea of tonal attraction specifically (Woolhouse, 2007, 2009). Woolhouse and Cross (2010) suggest that the tonal hierarchies that resulted from Krumhansl’s probe tone studies could be partly explained in terms of the particularly predominant “tonal attraction profile” of the dominant seventh chord.

It is evident that short-term pitch memory plays a central role in our ability to perceive pitch hierarchies and tonal forces. Diana Deutsch’s work is very important in this respect (for a complete review see Deutsch, 1999, pp. 349-411). For example, she studied the ways in which an interpolating sequence of tones can affect our short-term memory for pitch (Deutsch, 1972, 1978). Even more relevant for the present project, she provided empirical evidence supporting that, in certain situations, nonmusicians tend to hear two instances of the same pitch as two

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<sup>2</sup> The terminology “tonal attraction” has been borrowed from Woolhouse and Cross (2009).

different notes and vice versa. In one of her studies, subjects compared two pitches, each accompanied by a lower tone (i.e., two harmonic intervals were played and the participants were asked if the highest pitch of the first harmonic interval was the same as or different from the highest pitch of the second harmonic interval). When the pitches to be compared were equal but the harmonic intervals differed (oblique motion), subjects made more errors (i.e., they tended to perceive the pitches to be compared as different); and, reciprocally, when the pitches to be compared were different but the harmonic intervals were equal (parallel motion), the participants also made more errors (i.e., they tended to perceive the pitches as equal) (Deutsch, 1974).

The literature review above provides evidence to believe that, when we listen to tonal music, our perception of individual scale degrees (pitch classes within a tonal context) might be affected by the harmonic context in which they are introduced. In other words, our mental representation of equal or octave-related frequencies  $A$  might be modified by other frequencies  $B$  that, either simultaneously ( $B$  superposed  $A$ ) or in succession ( $B$  surrounding  $A$ ), affect the harmonic context. It is well known that, in tonal music, the degree of stability of individual pitches changes with the harmonic setting. For instance, scale degree  $\hat{4}$  is stable within a  $IV$  chord (because it is the root of the chord) but unstable within a  $V^7$  harmony ( $7^{th}$  of the chord). This suggests that harmony affects our perception, and thus cognitive representation, of individual tones. In accordance with Krumhansl's principle of contextual distance mentioned above, we should expect a modification in the tonal stability of a certain scale step, induced by a harmonic change, to engender different cognitive representations for that musical note. Moreover, greater changes in the tonal stability of a pitch (e.g., from highly stable to highly unstable) ought result in more pronounced differences in its cognitive representation.

The idea that the harmonic context of a given note has the potential to modify our perception of that tone finds its theoretical foundation in Ribeiro Pereira's *Theory of Harmonic Modulation* (2005). Conceived as an alternative paradigm to the Schenkerian linear approach and to the Riemannian harmonic dualism, Ribeiro-Pereira's model recaptures a pre-eighteenth-century view of modulation as harmonic movement both within a key and between keys. This reconceptualization of harmonic modulation is expressed by the change of harmonic context of a fixed object (scale degree, a collection of notes, or entire scale). The simplest form that this object can take is a scale degree. Following this, a scale degree can be "modulated" by the harmonic contexts through which it is presented. The model reinvigorates the plagal (subdominant) harmonic field, since it is this field that changes the harmonic context of the tonic. (Ribeiro Pereira, 2005).

With the purpose of illuminating our understanding of the cognitive representation of musical tones in moving harmony, this thesis proposes an empirical investigation of the perception of pitch in different harmonic settings at a local scale (i.e., within adjacent harmonies). Based on previous literature supporting the preponderant role of tonal context in our perception of classical music, it is predicted that harmony will have an effect on pitch discrimination. More over, in accordance with Krumhansl's principle of contextual distance, harmonically/tonally stable and unstable settings of the same pitch should elicit different cognitive representations.



## **CHAPTER 2**

### **Methodological Approach**

This thesis aims to study pitch perception in moving harmony by experimentally analyzing nonmusicians' ability to discriminate between equal and different tones as they are presented in changing and nonchanging harmonic contexts. The participants perform a same/different forced-choice task on two pitches (a reference tone RT and a comparison tone CT) that are introduced in a four-to five-measure melody with a clearly implied harmonic progression (i.e., for simplification purposes, the musical examples used in this thesis are monodic; thus, harmony is defined melodically).<sup>3</sup>

In tonal music, the alteration of an individual frequency within a larger musical sample implies changes in different aspects of pitch, such as scale degree, chroma, harmonic setting, intervallic context, and harmonic (or tonal) stability (Huron, 2006). In addition, the interpolation of notes between two tones to be compared (RT and CT, in this experiment) affects memory for pitch in certain situations and, consequently, pitch discrimination (Deutsch, 1999). Due to the strong interdependence of the different features of pitch, the study of individual aspects of pitch (such as harmony) should consider confounding (depending) factors. The fact that pitch perception can be influenced by many factors that often cannot be manipulated independently does not mean that any attempts to investigate a single aspect of pitch would be in vain, but rather that the investigation of individual factors should thoughtfully consider potential confounds. This thesis proposes an experimental design that aims to control for confounds in a way that should allow us to conclude about pitch-perception effects that are relatively specific to the incorporation of a changing harmonic context.

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<sup>3</sup> Further details about the experimental procedure are discussed in Section 3.1.1.

The study of pitch in harmonic context presents major methodological challenges. Given that it is precisely pitch what defines harmony (a harmonic context is a particular combination of notes), the succession of pitches and the harmonic progression that constitute a musical example (like the stimuli used for this study) cannot be manipulated with total independence. Because statistical analyses are based on comparative techniques, the most spontaneous experimental procedure to investigate pitch perception in changing harmony would juxtapose changing-harmony with nonchanging-harmony trials. Instinctively, an experimental design that contrasts stimuli in which the two notes to be compared (RT and CT, which can be same or different) are set in nonchanging harmony with examples in which the two notes are harmonized differently, should, in principle, provide information about the effects of harmonic context on pitch perception. However, a deliberate consideration of the problem reveals that such experimental design would be impractical and, more importantly, controversial (not to say inadmissible) in terms of confounding-factors control.

Two major problems impede balancing a design that includes both changing-harmony and nonchanging-harmony conditions. Given that we are interested in examining pitch perception in harmonic context, the design must include at least two factors, *Pitch* and *Harmony*; with two levels each, same and different, in the case of *Pitch*, and nonchanging and changing, in the case of *Harmony*. Table 2.1 illustrates the design in question. Letters are shown as references to illustrate the problems. The first problem is that the two levels of the *Harmony* factor (i.e., changing versus nonchanging harmony) cannot be balanced in terms of the effects of confounding factors. As it will be explained below, in Table 2.1, A+B is necessarily different from C+D. The second problem is that the two levels of *Pitch* (i.e., RT=CT: the two notes are the same pitch; and RT≠CT: the two notes are different pitches) cannot be neutralized in the

nonchanging-harmony condition. This means that in Table 2.1, C is different from D. Because statistical analysis assesses the significance of effects by probabilistically evaluating differences between conditions (or levels of conditions), the two problems of balance presented above obstruct a cogent study of pitch in harmony based on a comparison of changing-harmony and nonchanging-harmony situations.

		PITCH	
		RT = CT	RT $\neq$ CT
HARMONY	Changing Harmony	A	B
	Nonchanging Harmony	C	D

Table 2.1 Experimental design that contrasts changing with nonchanging harmony.

These issues of design balance arise from the impossibility to freely manipulate three confounding factors, namely intervallic context, number of different notes interpolated between RT and CT, and harmonic stability. With respect to the first confounding factor, design-balance issues emerge from the fact that RT and CT cannot be presented in equivalent intervallic contexts in the changing-harmony condition with respect to the nonchanging-harmony condition (thus, destabilizing A+B with respect to C+D in Table 2.1). Studies have shown that the intervallic context of a note affects pitch discrimination. Specifically, different pitches tend to be judged as equal when they are melodically approached in the same way (i.e., same melodic interval of approach), whereas equal tones are prone to be heard as different when the melodic intervals leading into them are dissimilar (Deutsch, 1982, 1999). Notice first that, because our aim is to measure people's ability to discriminate between same and different pitches (i.e., the

participants are performing a same/different discrimination task on two equal/unequal pitches), the stimuli must be consistent musical patterns with a similar melodic context for CT and RT. An experiment that maintains a homogeneous melodic context for the two notes minimizes confounds in that respect. It is precisely this within-stimulus consistency, an essential controlling factor, what impedes the manipulation of the intervallic context in nonchanging-harmony conditions. The presentation of two equal notes within a nonchanging harmonic context and a consistent melodic pattern (i.e., equivalent melodic context) invariably implies equal intervallic approach for CT with respect to RT; similarly, the introduction of two different notes (RT $\neq$ CT) within a static harmonic setting must entail dissimilar melodic approaches. Figure 2.1 shows an example. Consequently, in nonchanging-harmony situations, the discrimination of equal and different notes would be favored (or at least not disrupted) by the intervallic context.

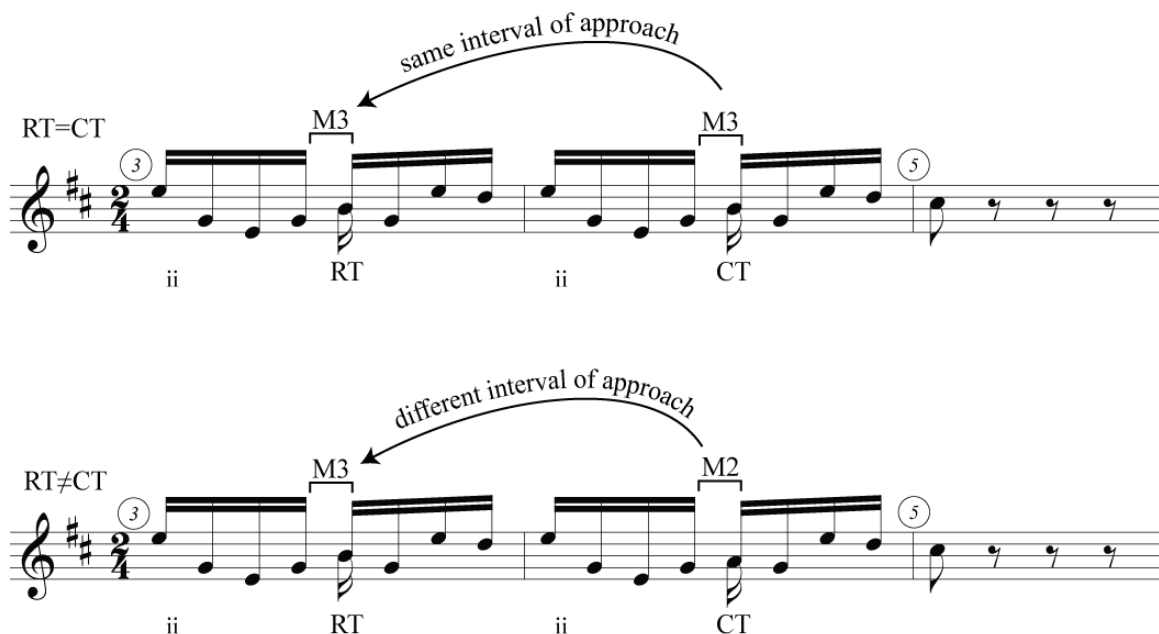


Figure 2.1 Interval of approach in nonchanging-harmony conditions.

This condition cannot be replicated in many changing-harmony situations, introducing a major problem to an experimental design that aims to compare conditions of changing and nonchanging harmony. More over, when the melodic pattern is kept relatively consistent, most harmonic progressions imply different intervallic approaches for equal notes and, conversely, similar (often exactly equal) melodic context for different notes (see Figure 2.2 for an example).

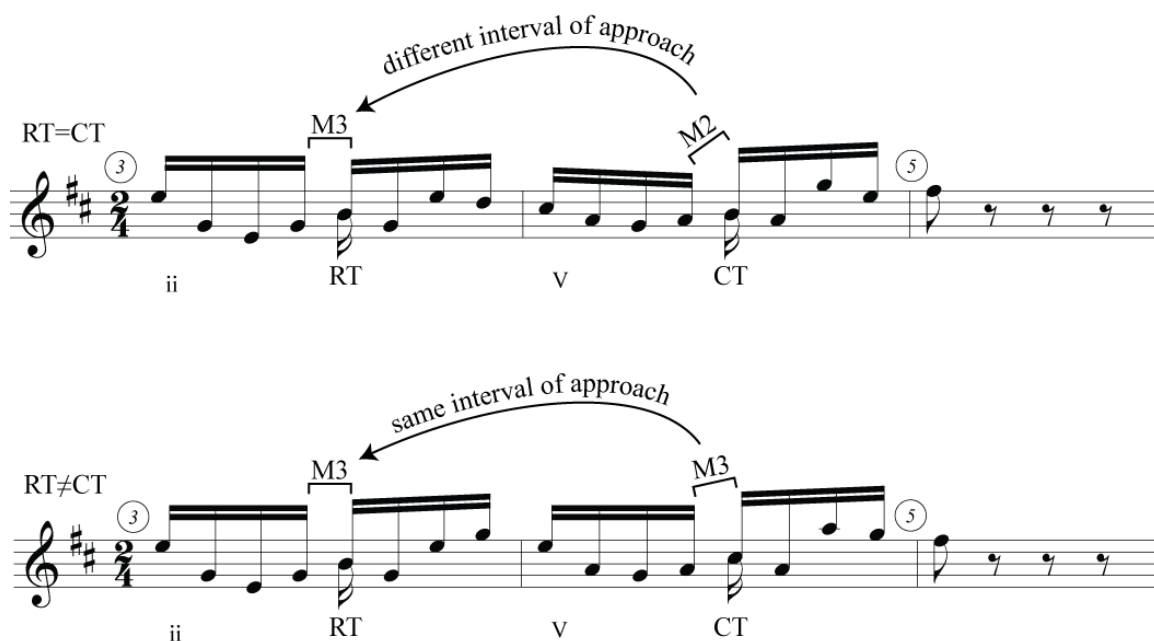


Figure 2.2 Interval of approach in changing-harmony conditions.

As a result, the intervallic factor would possibly affect pitch discrimination (i.e., difference between  $RT=CT$  and  $RT\neq CT$ ) positively (or neutrally, but never negatively) in the nonchanging-harmony condition and negatively in the changing-harmony condition (in Table 2.1, C+D would have a larger percentage of correct responses than A+B). In other words, pitch discrimination is likely to be considerably disrupted only in the changing-harmony condition. Ultimately, a statistical analysis that compares changing-harmony with nonchanging-harmony situations

would not allow us to conclude about the *Harmony* factor independently from the effects of intervallic context, because the difference between the two harmony conditions would be greatly influenced by the effects of unbalanced intervallic approaches.

Additional balancing problems arise from the impossibility to create stimuli of changing and nonchanging harmony with equivalent number of different notes interpolated between RT and CT. The number of different pitches between RT and CT is likely to disrupt memory for RT, which should affect the comparison of CT with RT and, in turn, the participants' ability to discriminate differences between the two pitches. Now, in order to assure that RT and CT have the potential to be influenced by harmony, they must be introduced in the middle of their respective harmonic contexts (in effect, as detailed in Section 3.1.2, the stimuli created for this study meet this characteristic). As a result, a changing harmonic context implies a larger number of different notes interpolated between RT and CT than a nonchanging harmonic context. An example is illustrated in Figure 2.3.<sup>4</sup> In other words, even when the number of unequal pitches can be held fairly constant across the two levels of *Pitch* for each of the *Harmony* conditions, it would tend to be higher at the changing level of *Harmony* than at the nonchanging level of *Harmony* (in Table 2.1, once again, C+D will have a larger percentage of correct responses than

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<sup>4</sup> Note that, in some cases, the incorporation of nonchord tones might permit matching of the number of different notes interpolated between RT and CT in the nonchanging-harmony condition with respect to the changing-harmony situation. Nevertheless, an exact matching would be impractical in many cases, mostly due to nonchord-tone treatment (e.g., many nonchord tones could not be treated properly, because RT and CT cannot be introduced as interpolated notes). More importantly, even in those cases in which the introduction of nonchord tones would allow for an exact match of the number of interpolated notes in the nonchanging-harmony situation and the changing-harmony condition, the use of nonchord tones would often disturb the melodic consistency of the pair (the *Pitch* pair, i.e., the RT=CT stimulus with respect to the RT≠CT pair; and/or the *Harmony* pair, i.e., the changing-harmony example with respect to the nonchanging-harmony pair) and/or interfere with the definition of the harmonic context (in the examples used for this study, harmonic definition is always a priority, even when some nonchord tones are used to add variety and make the stimuli more real from a musical point of view).

A+B). This inequality could easily reduce the subjects' ability to discriminate pitch in changing harmony with respect to static harmony, interfering with a statistical comparison between the two harmony conditions.

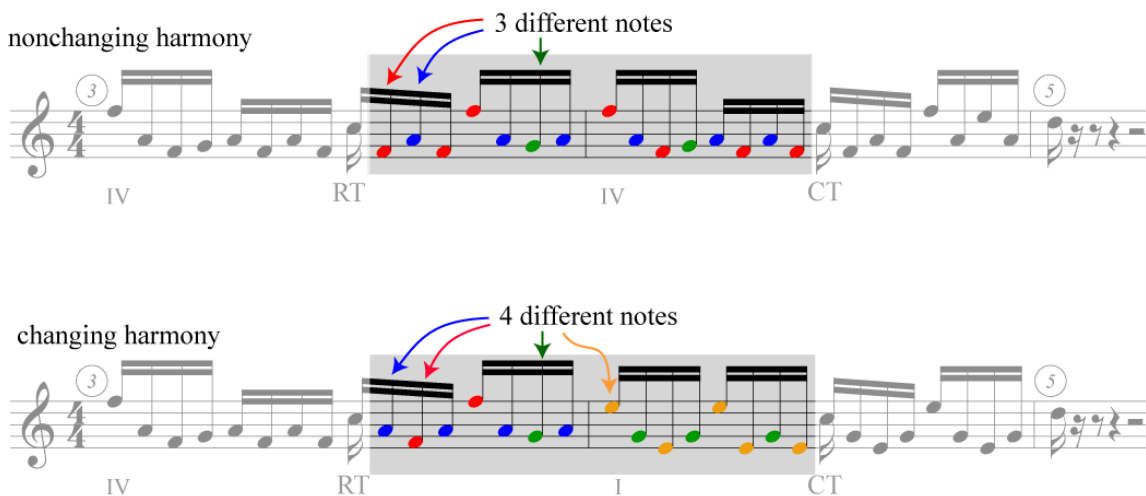


Figure 2.3 Number of different notes interpolated between RT and CT in nonchanging-harmony and changing-harmony conditions.

Lastly, an experimental design that contrasts changing-harmony with nonchanging-harmony conditions would be unbalanced with respect to harmonic (or tonal) stability (i.e., whether RT and CT are consonant or dissonant in their respective contexts). In terms of harmonic stability, a study of harmonically contextualized pitch discrimination should balance stimuli in which RT and CT are equally stable (i.e., both notes are consonant –chord members) with examples in which the two notes are unequally stable (i.e., one of them is a chord tone, whereas the other is a nonchord tone). An experimental design that incorporates a harmonic-stability factor is advantageous in two respects: it controls for confounds, by perfectly balancing all levels of a potential influencing factor in both the  $RT=CT$  and  $RT \neq CT$  conditions; and it provides further information with respect to the effects of harmonic context on pitch perception,

by examining pitch discrimination in harmonically stable and unstable situations. Whereas careful planning allows for balance not only at all levels of the *Harmonic Stability* factor (i.e., equal stability and unequal stability) but, most importantly, at the two levels of *Pitch* (RT=CT and RT≠CT) in changing-harmony conditions, serious harmonic-stability inequalities between the two levels of *Pitch* are inevitable in nonchanging-harmony situations. As a result, aspects of harmonic stability are only analyzable in changing harmonic contexts and, more importantly, they have the potential to disproportionally interfere with pitch discrimination in nonchanging-harmony conditions (in Table 2.1, C has the potential to be different from D, because the effects of harmonic stability on pitch perception are unknown). It is evident that equal notes in static harmony must be equivalent in terms of harmonic stability. Conversely, an attempt to control for the distance between the different notes in the RT≠CT situation unavoidably results in different harmonic stability for RT with respect to CT.<sup>5</sup> Finally, when equal notes are presented in a

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<sup>5</sup> The goal of this thesis is to investigate pitch perception by evaluating pitch discrimination (same versus different pitch) abilities. Because participants are differentiating between only two situations (i.e., they are forced to respond whether two notes are the same or different), it is very important to specify these conditions in a consistent manner. The similarity of two pitches is determined by the distance (interval) between them. Whereas the distance between two equal notes must be null, different [nonnull] intervals define a range of dissimilitude for pairs of unequal pitches. In other words, two notes that are not the same can be different with multiple degrees (e.g., slightly different or very different). From this point of view, the category “equal pitches” (RT=CT) is indivisible whereas the condition “different pitches” (RT≠CT) contains sublevels. In order to maximize consistency within the stimuli with different notes, the interval between RT and CT is a second without exception. The interval of a second was chosen for being the smallest possible distance between two notes (further details in this respect can be found in Section 3.1.2). When two notes a-second-apart are introduced in a nonchanging triadic harmonic context (like it is the case here), either one of them must be a chord member and the other one a nonchord tone or they must both be nonchord tones. Notice that because this is a study of pitch perception in changing harmony, the definition of the harmonic context is of primordial importance and, thus, the incorporation of examples with two nonchord tones would present further problems. More over, when the harmony does not move, it is almost impossible to introduce two different nonchord tones in similar melodic (intervallic) contexts with proper dissonance treatment. Finally, in the nonchanging-harmony condition, all RT≠CT stimuli must consists of either chord tone followed by nonchord tone or vice versa (i.e., the two notes must be



nonchanging harmonic context, they must be equivalent in terms of harmonic stability, whereas when different notes are introduced in static harmony, they must be different in terms of harmonic stability (See Figure 2.4).

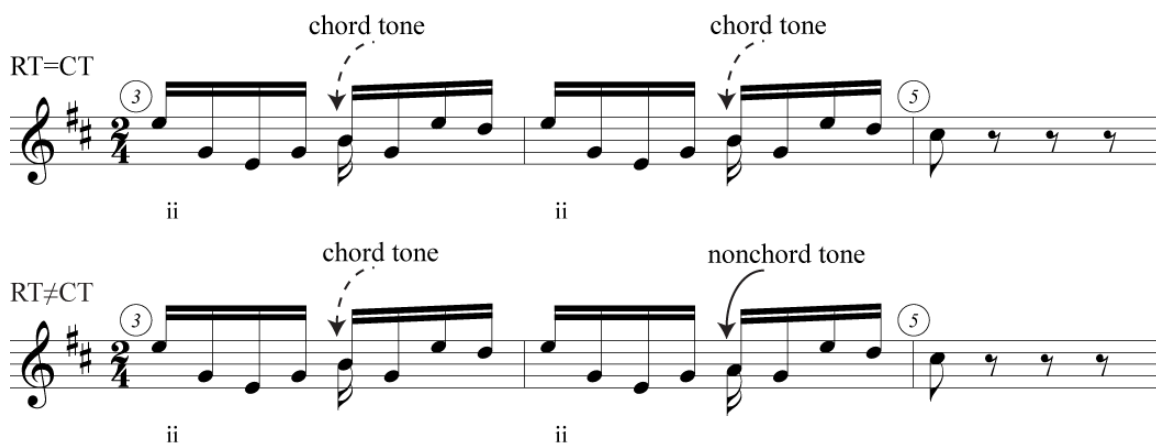


Figure 2.4 Harmonic stability of RT and CT in nonchanging-harmony conditions.

Because the effects of harmonic stability on pitch discrimination have not been previously studied (i.e., we do not know if harmonic stability affects pitch perception), the problem of design balance being discussed here might not be as crucial as the issues related to intervallic context explained above. Nevertheless, it is a potential problem that deserves consideration. In addition, beyond the unbalanced characteristics of an experimental design that compares changing-harmony with nonchanging-harmony conditions, given that the harmonic stability of a note is directly determined by its harmonic context, it seems reasonable to propose a model that incorporates a harmonic stability factor (and, due to the reasons explained in this paragraph, an

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unequal in terms of harmonic stability), whereas all RT=CT stimuli must be chord tone followed by chord tone, presenting potential problems due to imbalance.

experiment that contrasts changing with nonchanging harmony cannot treat harmonic stability as a factor).

Finally, an experimental design that compares pitch-discrimination ability in changing-harmony conditions with that in nonchanging-harmony situations (as illustrated in Table 2.1) would not allow us to conclude about the influence of harmony on pitch perception (any conclusions would be contaminated by confounds). The impossibility to freely manipulate intervallic context, number of different pitches between RT and CT, and harmonic stability would unbalance the experimental design. Specifically, intervallic context, number of different notes, and possibly harmonic stability, are likely to lead to different pitch-discrimination abilities at each level of the *Harmony* factor (i.e., in Table 2.1, we should expect differences in A+B with respect to C+D), and the harmonic stability of CT with respect to that of RT could potentially induce dissimilar percentages of correct responses for each level of *Pitch* in the nonchanging-harmony condition (i.e., in Table 2.1, C has the potential to be different from D). The details of the problems of a design that compares changing versus nonchanging harmonic situations are summarized in Table 2.2.

Instead, this thesis aims to study the effects of the incorporation of a changing harmonic context on pitch perception by proof of elimination. It proposes a balanced design that includes only stimuli with changing harmony and intends to be exhaustive in terms of known and potential confounding factors. It is precisely the symmetry of the design in most aspects of pitch what makes it suitable for the investigation of pitch perception in harmonic context. Whereas the proposed model cannot be used to examine the effects of changing harmonic context on pitch perception with respect to the effects of nonchanging harmonic context, it permits us to draw conclusions about the incorporation of a harmonic context that is, specifically, a changing

harmonic context. More importantly, the results of this analysis should be unaffected by confounding factors.

		HARMONY			
		Changing		Nonchanging	
		PITCH		PITCH	
		RT = CT	RT $\neq$ CT	RT = CT	RT $\neq$ CT
INTERVALLIC CONTEXT	Same	1/x of total number of stimuli	[1 -1/x] of total number of stimuli	Total number of stimuli	Not possible
	Different	[1 -1/x] of total number of stimuli	1/x of total number of stimuli	Not possible	Total number of stimuli
NUMBER OF DIFFERENT NOTES BETWEEN RT AND CT		y	y	$z < y$	$z < y$
HARMONIC STABILITY	Equal	1/5 of total number of stimuli	1/5 of total number of stimuli	Total number of stimuli	Not possible
	Unequal	1/5 of total number of stimuli	1/5 of total number of stimuli	Not possible	Total number of stimuli

Table 2.2 Problems of a design that compares changing with nonchanging harmony.

In addition, a supplementary experiment that included stimuli in nonchanging-harmony conditions was done with the only purpose of adding some extra information that could be pertinent to the topic in question, and with the caution that the interpretation of its results requires. The main and supplementary experiments are described in detail in chapters 3 and 4 respectively.

An explanation of how the main experimental design proposed in this thesis (i.e., experiment that includes only changing-harmony trials) considers confounding factors is

essential to understand the interpretation of the results. The study of pitch perception in harmony is indeed a contextualized analysis. Musical context is the result of the interplay of many factors. Therefore, the investigation of pitch in harmonic context cannot completely eliminate confounding components. Based on this, the proposed experiment aims to control (rather than eliminate) confounds by balancing their [possible or known] effects at the two levels of *Pitch* (RT=CT and RT≠CT). In this way, any disturbance of the subjects' performance due to confounding factors should be reflected equally in the RT=CT and RT≠CT conditions (since confounds are represented symmetrically, they should not create a statistically significant difference between the two levels of *Pitch*). In other words, the magnitude and direction of the effects of confounding factors on pitch discrimination should be equal for each level of *Pitch*. Five confounding factors are considered: (1) number of pitches between RT and CT; (2) number of different tones between RT and CT; (3) chroma; (4) scale degree; and (5) intervallic context. Notice that these aspects are manipulated with the only purpose of controlling for those features of pitch that, even when impossible to physically separate from the incorporation of a changing harmonic context, are not directly and conceptually related to harmony.

The first four confounding factors might interfere with a pitch-discrimination task by disrupting memory for the first pitch (RT)<sup>6</sup> and, consequently, the participants' judgment of CT as equal/different with respect to RT. In the proposed experiment, the number of pitches between RT and CT varies only among melodic patterns, which are equally represented at each level of *Pitch*. Therefore, the effects of the number of interpolated notes on pitch discrimination should be the same for the RT=CT and RT≠CT conditions (i.e., given that the number of interpolated

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<sup>6</sup> It is evident that scale degree and chroma might interfere with memory for CT also. However, such disruption is irrelevant for the purpose of comparing CT with RT, because CT (second note) is not the note that needs to be remembered in order to judge if the two notes are same/different. Control of scale degree and chroma are explained later in this paragraph.

notes is exactly equal in both conditions, RT should be remembered with the same accuracy across both levels of *Pitch*). In other words, the number of notes between RT and CT could be responsible for a reduced percentage of correct responses in each condition (with respect, for instance, to noncontextual pitch-discrimination situations where the second note is presented immediately after the first one), but not for a difference in the subjects' performance in the RT=CT condition with respect to the RT $\neq$ CT condition. Similarly, the number of different notes between RT and CT should not affect the two levels of *Pitch* differently. Each stimulus in the RT=CT condition is paired with a stimulus in the RT $\neq$ CT condition. Pairs of examples are basically equal.<sup>7</sup> As a result, the notes between RT and CT are basically the same for paired stimuli: all cases are represented equally across both levels of *Pitch*. Chroma is an inherent property of nonregistrally-defined pitch: different pitch classes correspond to different chromas. In the context of this experiment, different/same pitches uniformly imply different/same pitch classes (i.e., RT and CT are always introduced in the same register, so that RT=CT means both equal pitch and equal pitch class and RT $\neq$ CT means different pitch and different pitch-class). Following this, under the proposed experimental design, a same/different chroma discrimination task is equivalent to a same/different pitch discrimination task. Similarly, in a fixed diatonic tonal context, the seven possible scale degrees parallel perfectly with seven chromas; therefore, scale degree should not alter, in principle, the performance of a comparison task between same/different pitch-classes. Pairs of stimuli are presented in exactly the same nonchanging diatonic tonal context and, thus, different/same scale degrees correspond to different/same pitch-classes. Nevertheless, scale degree differs from pitch and chroma in that it is hierarchical (in effect, a scale degree is a rank of a certain pitch class or chroma in a tonal context). In effect, it is

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<sup>7</sup> Further details about the characteristics of a pair can be found in Section 3.1.2.

known that scale degree can alter the perceptual importance of single pitches, which, in the context of a comparison task, can interfere with memory (Krumhansl, 1990). Indeed, scale degree can affect memory for individual pitches (e.g.,  $\hat{1}$  is easier to remember than  $\hat{2}$ ) and, consequently, it could interfere with a same/different pitch discrimination task by altering memory for RT. In general, the scale degrees chosen for RT are equally distributed in the  $RT=CT$  and  $RT\neq CT$  conditions; more over, in many cases the pitch (and thus scale degree and chroma) that corresponds to RT is the same for each pair of stimuli. Therefore, scale degree and chroma should affect (or not) both levels of *Pitch* equally. Notice that scale degree and chroma can disrupt memory for pitch but not pitch perception per se, because the two factors are intrinsic (rather than contextual) to pitch and they vary consistently with pitch (i.e., given a tonal context, different scale degrees or chromas correspond to unique pitch classes and, thus, a pitch-discrimination task is equivalent to a scale-degree or chroma discrimination task).

The fifth confounding aspect (melodic interval of approach and resolution of RT with respect to that of CT) deserves special consideration. As mentioned above, research has revealed that the intervallic context of a note affects pitch discrimination. Different pitches tend to be judged as equal when they are melodically approached in the same way, and equal tones are prone to be heard as different when the melodic intervals leading into them are different (Deutsch, 1982, 1999). Furthermore, the magnitude of the effect appears to be very similar for each case.<sup>8</sup> The main experiment proposed in this thesis balances the situations in which unequal RT and CT ( $RT\neq CT$  condition) are approached (and resolved) in the same way (i.e., same interval of approach and resolution for CT with respect to RT when  $RT=CT$ ) with the stimuli in

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<sup>8</sup> Deutsch does not report effect size measures, but, because the two conditions are symmetrical parts of the same experimental design, it is valid to compare p values, which are the same for each case ( $p<0.005$ ). We can thus conclude that the magnitude of the effect is similar.

which equal RT and CT (RT=CT condition) are approached (and resolved) in a different manner (i.e., different interval of approach and resolution for CT with respect to RT when RT≠CT).<sup>9</sup> Following this, even when it is known that intervallic context affects pitch discrimination, in the main experiment proposed here, the effects of intervallic context on pitch perception should have the same magnitude and direction in the CT=RT condition with respect to the CT≠RT condition (i.e., statistically significant differences between the two levels of *Pitch* should not result from variances in the intervallic context).

Finally, any difference in the participants' performance between the two levels of *Pitch* (i.e., difference in the percentage of correct/incorrect responses in the RT=CT condition with respect to the RT≠CT condition) must be explained by aspects of pitch other than intervallic context, number of notes between RT and CT, number of different tones between RT and CT, scale degree, and/or chroma. The main experiment proposed in this thesis incorporates a changing harmonic context in all the stimuli at the same time that treats variations in harmonic (tonal) stability as a [balanced] factor.<sup>10</sup> In this way, the design aims to be exhaustive by considering the most relevant aspects that might affect pitch discrimination within a changing harmonic context: it considers all aspects that could disrupt pitch perception, either by balancing those factors that could potentially (or are known to) have an effect on pitch (and consequently removing any possible difference between the two levels of *Pitch*), or by statistically accounting for (i.e., treating as factors) those aspects whose effect on pitch is unknown (i.e., variations in harmonic stability). This means that differences (if any) in the discrimination of equal pitches with respect to different pitches (i.e., statistically significant variance between the two levels of

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<sup>9</sup> Further details about the manipulation of the intervallic context within examples (rather than at the level of the experimental design) are discussed in Section 3.1.2.

<sup>10</sup> The details of the experimental design are discussed in Section 3.1.3.

*Pitch*) should be explained by harmonic stability, and/or harmonic context that, in this particular case, is specifically a changing harmonic context (because all stimuli are examples of moving harmony). Furthermore, because both levels of *Pitch* and *Harmonic Stability* are mutually exclusive and exhaustive, an analysis of the interaction between *Pitch* and *Harmonic Stability* accounts for those differences between the two levels of *Pitch* that are due to changes in harmonic stability. Notice that, even when *Harmonic Stability* is balanced, we cannot predict that its effects on its interaction with the main factor *Pitch* (i.e., difference between the effects of *Harmonic Stability* at each level of *Pitch*) will be null, as we did with confounding factors 1 to 4. Harmonic stability resembles intervallic context (confounding factor 5) in that they are both contextual. The harmonic stability of a single pitch varies according to the harmonic context: harmonic stability is not a property of pitch per se, but rather an aspect of pitch that, in addition to be directly related to harmony (and thus of great interest for this investigation), could influence pitch perception in different [unknown] ways. The two levels of *Pitch* (RT=CT and RT≠CT) could potentially be affected *differently* by the harmonic stability of RT/CT. Finally, a statistically significant interaction between *Pitch* and *Harmonic Stability* is possible because (1) the effects of harmonic stability on pitch are unknown, and (2) harmonic stability is determined by context rather than being an intrinsic feature of pitch; that is, it has the potential to affect the perception of both (or either) pitches per se and not just memory for RT.

As a conclusion, this study intends to examine pitch perception in changing-harmony conditions by proposing an experimental design that aims to be exhaustive in terms of the different aspects that might affect pitch perception. Because the design balances the two levels of *Pitch* at each level of nearly all known and possible confounds, any differences between the CT=RT and RT≠CT conditions must be due to either or both of the remaining aspects of pitch:



harmonic context and/or harmonic stability. In the present experimental design, harmony is [invariably] represented by the incorporation of a changing harmonic context and harmonic stability is a factor of analysis. This is precisely what allows us to specify the conclusions to changing-harmony conditions. In this way, the main experiment proposed in this thesis is suitable for the examination of how the incorporation of a changing harmonic context (that includes fluctuations in harmonic stability) affects pitch discrimination: the results should account for a reduced ability to discriminate pitch differences in the  $RT=CT$  condition with respect to the  $RT\neq CT$  condition or vice versa; or, what it is the same, they should reflect if the participants are confusing same for different or different for same, which is precisely the matter of this study.

It should be evident that the proposed design has an important limitation, namely that it does not allow for the evaluation of the effects of changing harmonic context that are equal in magnitude and direction at both levels of *Pitch*. For instance, this model cannot account for possible reductions in pitch discrimination abilities, caused by the incorporation of harmony, that occur symmetrically in the  $RT=CT$  and  $RT\neq CT$  conditions. This is because such reductions could be (and possibly are, at least in part) caused by confounding factors, whose disruptive effects on pitch discrimination can be balanced at the two levels of *Pitch* (so that they do not create a difference between the  $RT=CT$  and  $RT\neq CT$  conditions), but cannot be completely neutralized (so that they have absolutely no effect on pitch perception). For instance, the number of notes between RT and CT probably affects the participants' memory, consequently reducing their pitch-discrimination ability in both the  $RT=CT$  and  $RT\neq CT$  conditions. As a result, the percentage of correct responses should be lower in the examples presented here than in noncontextual situations (or situations with a smaller number of notes between RT and CT). In

effect, it is likely that the confounding factors mentioned above will reduce the participants' ability to discriminate pitches; and, because no procedures allow us to determine the exact amount of the reduction that corresponds to confounding factors, the proposed design cannot account for possible symmetrical (i.e., equal in magnitude and direction for  $RT=CT$  and  $RT\neq CT$ ) reductions/enhancements in pitch discrimination that are due exclusively to the incorporation of a changing harmonic context.

This limitation originates from the fact that it is not possible to design an experiment that could account for pitch-perception differences between changing-harmony and nonchanging-harmony conditions without a problematic interference of confounding factors. In an attempt to partially compensate for this limitation, this thesis proposes a supplementary experiment that compares changing-harmony with nonchanging-harmony situations. An additional set of stimuli in nonchanging-harmony conditions was created, paralleling the stimuli of the main experiment. A two-factor (*Pitch*, *Harmony*) between-subjects ANOVA compares the supplementary addition (that works as nonchanging-harmony condition) with the original experiment (that now works as changing-harmony condition). Even when the results of this comparison are greatly affected by confounds (and, thus, this experiment does not allow us to conclude about the effects of harmony specifically), it should provide an idea of how pitch perception is affected in changing-harmony versus nonchanging-harmony situations as they are most likely to occur in music (e.g., if two equal chord tones appear in the same harmonic context, they will always be equally stable from a harmonic point of view, whereas if two equal notes are presented in a changing harmonic context, they might or not be equally stable). In addition, with the purpose of reducing the effects of confounding factors, an ANOVA compares the supplementary stimuli with only those stimuli from the main experiment that parallel the added examples in terms of intervallic context (i.e.,

changing-harmony stimuli with equal intervallic approach for RT and CT in the  $RT=CT$  condition and different intervallic approach in the  $RT\neq CT$  situation). Similarly, a statistical contrast of the nonchanging-harmony condition to only those examples from the changing-harmony condition that are equivalent to the supplementary stimuli in terms of harmonic stability (i.e., changing-harmony stimuli with equal harmonic stability in the  $RT=CT$  condition and unequal harmonic stability in the  $RT\neq CT$  situation), could illuminate the topic in question. It is important to point out that, whereas the latter two analyses should provide information about the effects of changing harmony with respect to nonchanging harmony that is less contaminated by confounds, they represent a relatively small population of combinations of harmonic progressions and melodic patterns. Finally, note that these analyses are likely to be affected by other confounding factors. The analysis that considers examples that are equivalent in terms of intervallic context is likely to be affected by harmonic stability and number of different notes between RT and CT. For instance, in all the changing-harmony examples in which  $RT=CT$  and RT and CT are melodically (intervallically) approached in the same way, the harmonic stability of RT must necessarily be different from that of CT, because chord progressions with two common tones are excluded for reasons explained in Section 3.1.2; whereas in all the changing-harmony examples in which  $RT\neq CT$  and RT and CT are approached differently (different interval of approach), the harmonic stability of the two notes is equivalent (in the patterns used for this thesis, both notes are chord tones). Conversely, as explained earlier in this section, in all nonchanging-harmony stimuli, the harmonic stability (and intervallic context) must be equal in the  $RT=CT$  condition and different in the  $RT\neq CT$  condition. Likewise, the analysis that includes stimuli that are equal with respect to harmonic stability could be affected by intervallic context and the number of different notes between RT and CT. In effect, changing-harmony examples

with equal stability for equal RT and CT (equal\_stability|RT=CT) invariably correspond to stimuli with different intervals of approach for CT and RT (simply because harmonic progressions with two common tones were intentionally avoided), precisely the opposite to what happens in the nonchanging-harmony condition.

## **CHAPTER 3**

### **Main Experiment**

#### **3.1 Method.**

##### **3.1.1 Procedure.**

Nonmusicians performed a same/different discrimination task on two pitches (a reference tone RT and a comparison tone CT) that were embedded in a four-to five-measure melody with a clearly implied harmonic progression. Color numbers appeared on a black computer screen, facilitating the identification of the two notes. A qualification test at the beginning of the experiment evaluated people's ability to discriminate differences in pitch (same vs. different) in nonnoisy conditions (the task was to compare two notes presented in succession). Only those people who completed this test with 100% correct responses (90% of the total number of subjects) participated in the experiment. A practice trial was included in the instructions page of the experiment, after the qualification test.

##### **3.1.2 Stimuli.**

Sixty audiovisual stimuli (duration  $M = 11$  seconds) were created specifically for this study. The musical examples, shown in Appendix A, consisted of a melody with a clearly implied harmonic progression. For each stimulus, the participants performed a same/different discrimination task based on the pitch of two tones (RT and CT) that appeared as part of two adjacent arpeggiated harmonies embedded in a longer progression. The examples were created using Finale grandpiano sound. Each excerpt was four- to five-measure long with a consistent rhythm. According to conventional tonal harmony, harmonic changes occurred on downbeats. The metrical position of RT and CT was the same across samples: they fell on the middle (semistrong beats) of measures three and four respectively. In this way, RT and CT were

preceded and followed by their respective harmonic contexts. The purpose of the first two measures was to provide a key, melodic, and rhythmic context to the listener. In order to facilitate the identification of RT and CT, color numbers appeared on a black computer screen. A large green number zero was synchronized with each of the two notes. Additional numbers falling on the two beats preceding RT and CT anticipated the arrival of the large green number zeros. They were red and smaller than the green number zero and they counted backwards (regressive count), in most cases from two to one.<sup>11</sup> An example of the stimuli used for the study can be found at <[http://www.youtube.com/watch?v=gxHAP0\\_pnNo](http://www.youtube.com/watch?v=gxHAP0_pnNo)>. A pilot survey was done to determine the distance between the two notes, speed and other parametrical aspects of the stimuli, assuring that the difficulty level of the task was appropriate for nonmusicians. Fifteen melodic patterns were tested and decisions were made based on the participation of twelve nonmusicians. In the pilot survey, the subjects were not forced to respond same or different, but given a third “I-cannot-tell” option in which they were asked to specify the reasons for not being able to make a same/different response. The patterns in which at least one participant indicated the third option were excluded from the actual study.

To minimize confounds related to pitch memory across samples, each stimulus was randomly assigned to a different key. In addition, as a general rule, repetitions of the notes to be compared (RT and CT) were avoided. The visually cued presentation of RT and CT was always isolated from other statements of the pitch classes of RT and CT within the same stimulus: RT and CT were never anticipated immediately preceding the cued appearance of RT, repeated between the cued presentations of RT and CT, or restated after the presentation of CT. When the

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<sup>11</sup> When RT and CT were separated by only one beat (see melodic pattern 2 in Appendix A), the number 2 that anticipated CT was omitted, so that the visual count of the entire stimulus was 2 1 0 (RT falling on 0) 1 0 (CT falling on 0). The stimuli of this type contained a warning message for the participants.

pitch classes of RT and CT were heard before the visual signs, they appeared as a pair (both or neither note) and they were relatively distant from the RT cue. Finally, within each example, even though differences in the melodic intervallic context of CT and RT (i.e., interval of approach and resolution) were unavoidable, they were minimized as much as possible so that CT and RT were approached and left in a similar (exactly the same, when possible) manner. The direction of the interval of approach/resolution of CT and RT was consistent within each stimulus. Furthermore, the difference between the intervals of approach and resolution of CT with respect to those of RT was never larger than a step. In addition, with relative consistency, the interval of approach of CT and RT was also very similar at the middle and/or large hierarchical levels of the melody.

Stimuli were organized in pairs (Appendix A maintains this arrangement). Two examples of the same pair were basically equal with the exception that in one case RT and CT were the same pitch and in the paired case they were different notes. To minimize the effects of confounding factors, the two examples of a pair were composed as equally as possible. The very few differences between them were adjustments needed to (1) avoid the repetition of RT/CT, (2) specify the harmonic context, (3) avoid unconventional melodic motions (e.g., to treat a nonchord tone or a large leap correctly, to resolve a tendency note, etc.), or (4) adjust the interval of approach/resolution of CT/RT so that it could be consistent (i.e., as similar as possible) within the sample. In addition, occasionally, some notes were changed at the beginning of the pattern (i.e., outside the context of cued RT/CT) to provide melodic consistency and/or to assure that RT and CT were both or neither anticipated before the cued appearance of RT.<sup>12</sup>

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<sup>12</sup> When possible, the changes were made to both the model and the pair.

In accordance to the results of the pilot survey, three different melodic patterns were chosen to provide variety in terms of melodic and intervallic context of RT/CT, speed, meter, etc. For simplification purposes, only major keys were tested. RT and CT were introduced as part of ten harmonic successions. The most common harmonic progressions in western classical music were equally represented in each of the three melodic patterns: I-IV, I-V, ii-V, ii-vi, iii-vi, IV-I, IV-V, V-I, vi-ii, vii-iii. Weak progressions were avoided because they do not imply a change in main harmonic function (tonic vs. subdominant vs. dominant). In addition, incorporating weak harmonic progressions would have added considerable problems to the composition of the musical examples, mainly due to note-repetition limitations. Because each of the three melodic patterns included one pair of stimuli representing each of the ten progressions, the total number of musical examples was sixty. In other words, the given number of stimuli was needed to introduce RT and CT in the most common harmonic contexts in three different melodic patterns.

In order to control for harmonic/tonal stability of RT and CT (i.e., whether RT/CT were consonant or dissonant) within their respective harmonies, both notes were presented as chord members and nonchord tones an equal number of times and in a symmetrical manner in terms of the experimental design.<sup>13</sup> The harmony implied in the context of CT and RT was as specified as possible. In 25% of the stimuli, the harmonic context of CT or RT was slightly ambiguous in the sense that it was missing a chord member (the fifth of the chord was missing in ten examples, and the root of the chord was omitted in five stimuli). For instance, in some cases in which CT or RT was the only statement of a chord member (a situation that occurred in all the examples in which CT/RT was a chord member, simply because restatements of CT/RT were avoided) in one

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<sup>13</sup> Details about how the design balances changes in harmonic stability are discussed in Chapter 2 and Section 3.1.3.



stimulus and a nonchord tone in the paired stimulus, it was impossible to unambiguously define the harmonic context of CT/RT. An attempt to specify the harmonic context in these situations would have implied either restating the note that was a chord tone in both [paired] stimuli or completely altering the pair with respect to the model. To minimize confounds that could result from harmonic ambiguity, when the harmony was incomplete, the possible implied harmonies belonged to the same harmonic function (e.g., an interval of a third that could imply either I or vi). Finally, it is important to note that, in a very few cases, unusual second inversions had to be used in order to enable the introduction of CT/RT within a specified harmonic context, to avoid an exact anticipation of the context of CT/RT, or to maintain the melodic pattern relatively consistent across samples. Nevertheless, because the examples were monodic, the lower note of a given passage did not necessarily convey a chord inversion.

### 3.1.3 Design.

The main study was a repeated-measures experiment with two factors. The dependent variable, pitch perception, was measured in percentage of correct responses (i.e., “same”|RT=CT and “different”|RT≠CT, where quotation marks indicate response types). The main factor of interest, *Pitch*, comprised two levels:

- (1) RT=CT: RT and CT corresponded to exactly the same frequency.
- (2) RT≠CT: RT and CT were different pitches. Within single stimuli, RT and CT were an interval of a second apart in the totality of the cases that corresponded to this condition. The interval of a second was chosen for being the smallest possible distance between two notes in the tempered tuning system: because we are examining people’s ability to discriminate between same and different tones, it seemed reasonable to minimize the difference between the pitches in the RT≠CT condition.

Furthermore, the smallest possible difference (interval) between two notes should be representative of the other (larger) distances or, at least, of all distances smaller than an octave (in the context of this experiment, “equal notes” means equal pitches and pitch classes, and “different notes” implies different pitches and pitch classes).

Based on the importance of harmonic stability of pitches in perceptual aspects of tonal music and with the purpose of controlling for confounds associated with the consonant/dissonant context of tones, a second factor of interest, *Harmonic Stability*, was incorporated into the design. This factor had two levels:

- (1) Equal stability: RT and CT were both consonances (chord members) in their respective harmonic contexts.
- (2) Unequal stability: RT and CT were considerably different in terms of stability within their harmonies. One of the two notes was a dissonant nonchord tone, whereas the other one was a stable member (chordal root, third, or fifth) of its contextual harmony.

Table 3.1 illustrates the distribution of chord tones and dissonant nonchord tones within pairs of stimuli and conditions. The first four columns show the number of stimuli in which cued CTs and RTs appeared as chord tones and nonchord tones in each condition. Note that because each stimulus contained one cued RT and one cued CT, the numbers that are shown in the first four columns do not reveal the number of examples heard. The latter number appears in the last column. For instance, the fifteen consonant (chord tones) reference tones and fifteen consonant comparison tones shown in the first row correspond to a total of fifteen stimuli. Colors show different types of pairs of stimuli. Color red corresponds to those pairs in which both CT and RT were treated as chord tones (i.e., equal stability) in the RT=CT condition and one note (either RT

or CT) was treated as a nonchord tone (i.e., unequal stability) in the corresponding pair (RT≠CT condition). Notice that, for each condition, the number of stimuli in which RT was a nonchord tone equaled that in which CT was a nonchord tone.<sup>14</sup> Conversely, color blue represents pairs in which CT and RT were treated as nonchord tones in the RT=CT condition, and one note was treated as a chord tone in the corresponding pair (RT≠CT condition).

	RT		CT		Number of Stimuli
	Chord tone	Nonchord tone	Chord tone	Nonchord tone	
<b>RT = CT</b>	15		15		15
	7	8	8	7	15
<b>RT ≠ CT</b>	8	7	7	8	15
	15		15		15
					TOTAL: 60

Table 3.1 Distribution of chord tones and nonchord tones within pairs and conditions.

The complete design is illustrated in Table 3.2. To summarize, the total number of stimuli was sixty (thirty pairs). In 50% of the stimuli (and pairs), RT and CT were the same pitch (RT=CT condition) and in the other 50%, they were different pitches (RT≠CT condition). In addition, each condition was equally divided between stimuli in which RT and CT were chord tones or, what it is the same, consonant within their harmonies (equal harmonic stability), and stimuli in which either RT or CT was a nonchord tone (the two notes had considerably different degrees of stability: consonance versus dissonance –unequal harmonic stability).

<sup>14</sup> As mentioned above, the purpose of introducing RT or CT as a nonchord tone was to differentiate the contextual stability of RT with respect to that of CT; thus, the note that was assigned to the nonchord-tone situation was irrelevant (the most important point was that the stability of one note was different from that of the other). Even when decisions about the assignment of the nonchord tone could have followed compositional practicality (facilitating the creation of the examples), they prioritized design balance in order to minimize possible confounds.

		PITCH	
		RT = CT	RT ≠ CT
HARMONIC STABILITY	Equal stability (RT and CT are both chord tones)	15 stimuli	15 stimuli
	Unequal stability (either RT or CT is a nonchord tone)	15 stimuli	15 stimuli

Note: All the stimuli correspond to changing-harmony conditions.

Table 3.2 Main experimental design.

### 3.2 Results.

A two-factor (*Pitch*, *Harmonic Stability*) repeated-measures ANOVA ( $n = 363$  nonmusicians, age 18-33) with percentage of correct responses as dependent variable<sup>15</sup> and  $c$  values (measures of response bias)<sup>16</sup> as covariate was performed. By calculating  $c$  for individual subjects and treating it as covariate, this analysis removed the effects of any possible response bias of the subjects. The analysis revealed significant effects of *Pitch* and *Harmonic Stability* that were qualified by a significant interaction between the two factors. The subjects discriminated equal notes ( $M_{\text{same}} = 0.674$ ,  $SD_{\text{same}} = 0.006$ ) significantly more accurately than different notes ( $M_{\text{different}} = 0.582$ ,  $SD_{\text{different}} = 0.006$ ):  $F(1,361) = 44.31$ ,  $p$  (adjusted Huynh-Feldt)  $< 0.001$ ,  $\eta^2 = .109$ . This implies that the participants perceived different pitches as equal more often than they heard identical notes as different. We can then conclude that the incorporation of a changing

<sup>15</sup> The same analysis was performed using percentage of incorrect (rather than correct) responses as dependent variable. The results were basically the same, with slightly different  $F$  values ( $p$  and  $\eta^2$  were the same as in the analysis with percentage correct as dependent variable). This is because correct responses in same trials are complementary with incorrect responses in different trials and vice versa.

<sup>16</sup>  $c = -1/2 [z(\text{"different"}|\text{DIFFERENT}) + z(\text{"different"}|\text{SAME})]$  where quotations indicate responses and capital letters show stimuli.

harmonic context affects nonmusicians' ability to recognize different pitches more than it influences their capability to perceive equal tones. Figure 3.1 shows percentage of correct responses for same (RT=CT) and different (RT≠CT) trials.

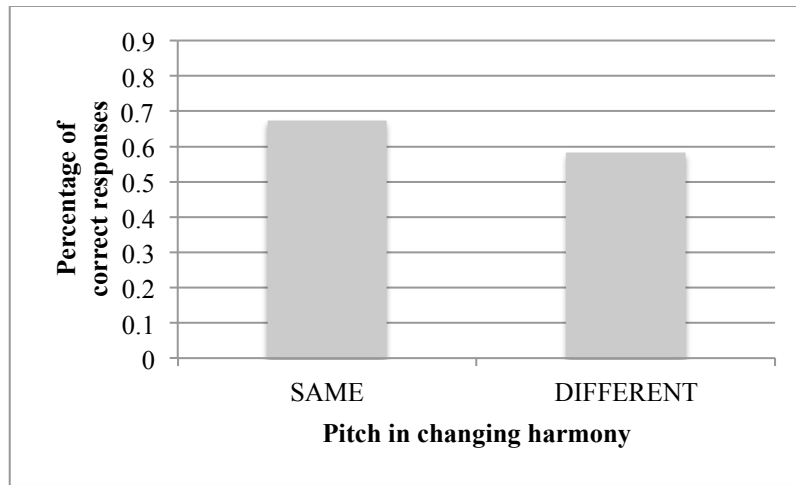


Figure 3.1 Discrimination of equal versus different notes in changing-harmony conditions.

In addition, the percentage of correct responses that corresponded to the stimuli in which the two pitches differed in terms of harmonic stability ( $M_{\text{unequal\_stability}} = 0.639$ ,  $SD_{\text{unequal\_stability}} = 0.006$ ) was significantly larger than the percentage of correct responses that corresponded to the examples in which the two notes were equally stable harmonically ( $M_{\text{equal\_stability}} = 0.617$ ,  $SD_{\text{equal\_stability}} = 0.006$ ):  $F(1,361) = 5.955$ ,  $p(\text{adjusted Huynh-Feldt}) = 0.015$ ,  $\eta^2 = .016$ . This is illustrated in Figure 3.2. A one-way (*Harmonic Stability*) repeated-measures ANOVA with *d-prime*<sup>17</sup> as dependent variable confirmed that the subjects were significantly more sensitive to discriminate same from different when one of the two notes was a nonchord tone ( $M_{d'_{\text{unequal}}} =$

<sup>17</sup> *D-prime* is a measure of the subjects' ability to discriminate between same and different that is free from response bias.

0.854 ,  $SD_{d'_{unequal}} = .47$ ) than when both pitches were harmonically stable ( $M_{d'_{equal}} = 0.754$  ,  $SD_{d'_{equal}} = .51$ ):  $F(1,362) = 5.527$  ,  $p(\text{adjusted Huynh-Feldt}) = 0.019$  ,  $\eta^2 = .015$ . The effects of *Pitch* and *Harmonic Stability* were qualified by a significant interaction:  $F(1,361) = 158.568$  ,  $p(\text{adjusted Huynh-Feldt}) < 0.001$  ,  $\eta^2 = .305$ .

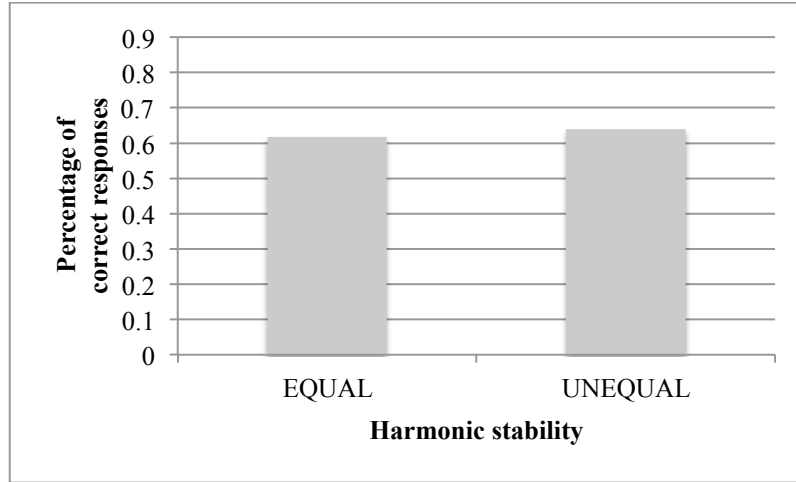


Figure 3.2 Pitch discrimination in equal versus unequal harmonic-stability conditions.

The pattern of means suggests that this interaction was due to the participants' ability to discriminate equal pitches that were both harmonically stable ( $M_{\text{equal|same}} = 0.709$  ,  $SD_{\text{equal|same}} = 0.008$ ) better than equal pitches with different harmonic stability ( $M_{\text{unequal|same}} = 0.638$  ,  $SD_{\text{unequal|same}} = 0.007$ ) and, conversely, their ability to discriminate different notes with unequal harmonic stability ( $M_{\text{unequal|different}} = 0.640$  ,  $SD_{\text{unequal|different}} = 0.008$ ) better than different notes with equal harmonic stability ( $M_{\text{equal|different}} = 0.524$  ,  $SD_{\text{equal|different}} = 0.007$ ). The interaction is illustrated in Figure 3.3. From this point of view, harmonic stability seems to affect pitch perception in a similar way than intervallic context: equal stability (specifically, consonant harmonic setting for both notes), like same interval of approach, appears to favor the perception

of equal pitches and disrupt the discrimination of different pitches; whereas unequal stability, like different interval of approach, has the converse effect.

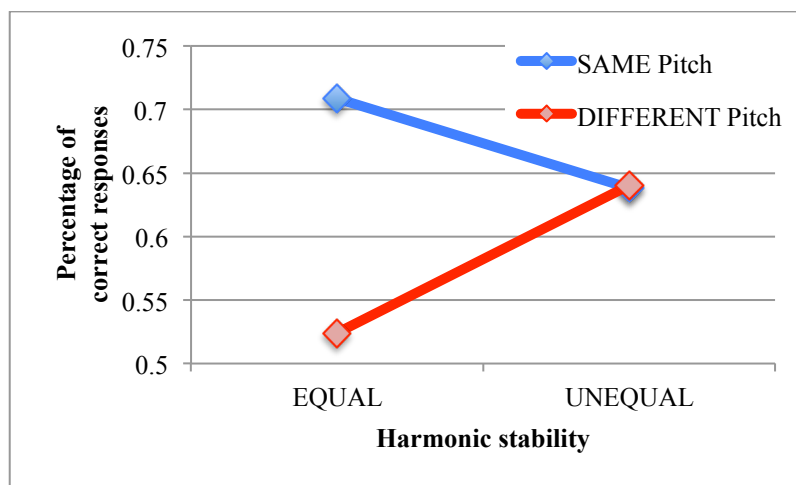


Figure 3.3 Interaction between *Pitch* and *Harmonic Stability*.

Finally, Figure 3.4 shows percentage of correct responses for individual stimuli<sup>18</sup> (i.e., specific harmonic progression and melodic pattern), organized according to pitch (RT=CT vs. RT≠CT) and harmonic stability (equally stable vs. unequally stable). Note the below-chance performance at the equal stability level of the RT=CT condition for melodic pattern 2, harmonic progression ii-V; melodic pattern 3, harmonic progression IV-V; and melodic pattern 3, harmonic progression vii-iii. These examples of RT=CT, unequal stability, received a higher percentage of “different” responses with respect to “same” responses (i.e. the percentage of incorrect responses was higher than the percentage of correct responses), implying that the participants perceived equal notes as different. The pairs of these three stimuli received among the highest percentages of correct responses (i.e., best subjects’ performance) in the RT≠CT,

<sup>18</sup> As shown in Appendix A.

unequal stability condition. Conversely, pattern 1, progression I-IV; pattern 1, progression ii-vi; and pattern 3, progression V-I, were among the most poorly judged examples within the  $RT \neq CT$ , unequal stability condition, and among the best rated stimuli in the  $RT = CT$ , equal stability situation.

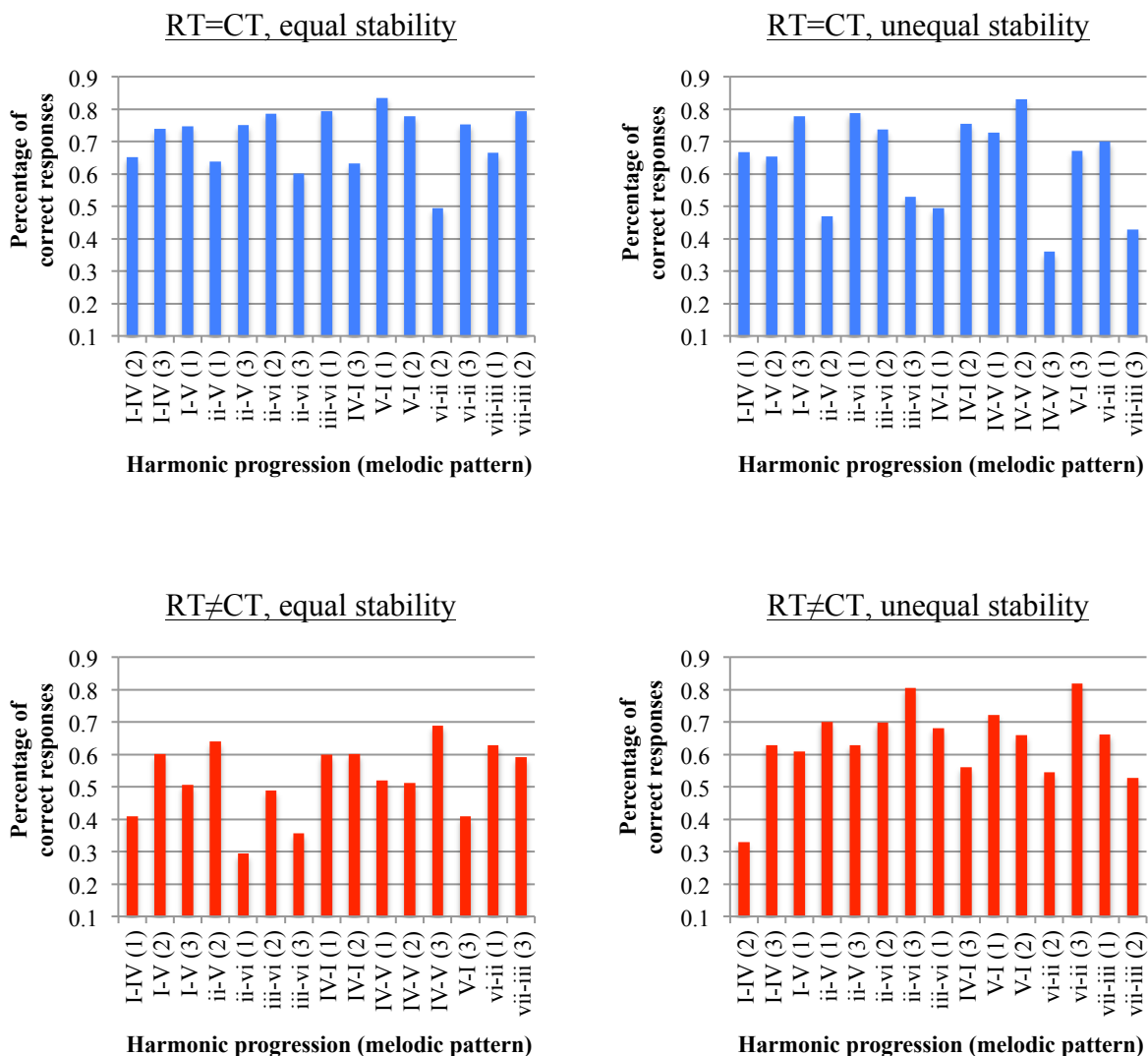


Figure 3.4 Discrimination of equal versus different pitches with equal and unequal harmonic stability, per individual stimulus.



These pairs of examples constitute the best illustrations of the effects of harmonic stability on pitch discrimination and the interaction between *Pitch* and *Harmonic Stability* described above. It is important to point out here that exactly 50% of these stimuli corresponded to situations in which the intervallic context of RT and CT was the same (i.e., same interval of approach) for the RT=CT condition and different for the RT≠CT condition. This suggests that intervallic context was not responsible for the differences in performance. Finally, considering that pairs of stimuli were composed as consistently as possible, we can conclude that the perceptual disruptions observed above were caused by changes in harmonic stability. Furthermore, because equal stability showed to interfere with pitch perception in the RT≠CT more than in the RT=CT condition and, conversely, unequal stability appeared to influence pitch discrimination in the RT=CT condition more than in the RT≠CT situation, pitch perception for paired stimuli was not greatly affected in the RT=CT, equal stability condition with respect to the RT≠CT, unequal stability condition (see top-left and bottom-right graphs in Figure 3.4). Pattern 2, progression I-IV was the only example within the RT≠CT, unequal stability condition in which the subjects performed below chance, deserving special consideration. A possible explanation for the observed decreased rate is that in this stimulus the nonchord tone, introduced in the second harmony (IV), worked as a substitute for the fifth of the chord, which was precisely the pitch of RT. It is important to point out that this musical example was not special in terms of intervallic context.<sup>19</sup>

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<sup>19</sup> In this example, RT and CT were approached equally (i.e., same interval of approach), as it was the case for most of the stimuli in the category RT≠CT, unequal stability.

### 3.3 Discussion.

Based on the central role of harmony in the definition of tonality and the well-established literature of contextual aspects of pitch perception, this thesis has hypothesized that harmonic setting affects pitch sensitivity and that the harmonic stability of a note shapes its cognitive representation. The main experiment investigated the effects of harmonic context and stability on pitch perception by examining nonmusicians' ability to discriminate equal and different notes (i.e., cognitive representation of pitch in its most basic form), of equal and unequal tonal stability, presented in a changing harmonic context. The results support that harmonic context shapes the cognitive representation of musical pitches by interfering with the perception of different tones more than with the perception of equal notes, and by defining the stability (or instability) of tones at the psychological (rather than acoustical) level. Overall, the outcomes of the main experiment suggest that a logical (conventional in tonal music) harmonic progression tends to bring together the percepts of musical notes that are introduced in adjacent chordal functions, particularly when the tones are stable (consonant) members of their contextual harmony.

The apparent perceptual closeness of tones that belong to contiguous harmonies of a changing harmonic succession is reflected in the main effect of *Pitch* observed in the statistical analysis of the main experiment. As predicted, the results showed a significant difference in discrimination abilities (measured in the participants' percentage of correct responses) for dissimilar with respect to identical pitches. Specifically, they revealed a greater disruption in pitch sensitivity for different than for equal pitches presented in moving harmony (this was discussed in Section 3.2 and illustrated in Figure 3.1). An incorrect "same" response is equivalent to a "different" response for a "same" stimulus, and an incorrect "different" choice is

equivalent to a “same” response for a “different” example. Following this, we can generalize that, in changing harmonic settings, nonmusicians perceive different notes as equal considerably more frequently than they hear equal pitches as dissimilar. On the whole, this suggests that tones introduced in adjacent components (i.e., harmonic contexts) of a moving harmonic progression tend to be perceived as equivalent (i.e., they occupy similar positions in the pitch-representation mental space).

This closeness of pitch percepts appears to be more pronounced when the notes introduced in contiguous functions of a changing harmonic succession are [consonant] members of their respective harmonies. This is reflected in the significant interaction between *Pitch* and *Harmonic Stability* observed in the data analysis of the main experiment (discussed in Section 3.2 and illustrated in Figure 3.3). As expected, and in accordance with Krumhansl’s principle of contextual distance (explained in Chapter 1), the results suggest that two pitches that are consonant within their respective harmonies are perceived as closer (i.e., more similar) to each other than two tones that are unequally stable (i.e., consonant versus dissonant). The statistical analysis revealed increased perception abilities for unequal with respect to equally stable notes that differed in pitch, but the opposite effect for equal tones. In other words, the results showed that the participants’ ability to discriminate two equal pitches was better when both notes were harmonically stable than when one of them was a dissonance, and, conversely, their sensitivity to two different tones was finer when one of them was a nonchord tone than when they were both equally stable harmonically. Taken one step further, these findings suggest that when two notes (equal or different) are unequally stable harmonically, they tend to be heard as different, whereas when they are both stable harmonically, they are prone to be perceived as equal. This, in turn, implies that the mental representation of a pitch is at least partly shaped by its tonal stability. It is

particularly relevant that in this study the stability of the notes was defined melodically (horizontally rather than vertically). In effect, what determined whether RT and CT were consonant or dissonant notes was precisely the [melodically set] harmony (and not other factors such as vertical interval, in which case the dissonant state of the notes would be primarily an acoustic phenomenon). In other words, in the context of the main experiment, the tonal stability of RT and CT was defined only by the harmonic setting. In sum, the harmonic context determined the stability of the notes, influencing their perceptual representations. In effect, when RT and CT are isolated from their corresponding harmonies, their stability is undefined (i.e., they are merely two unrelated notes). As a final remark, notice that, because the harmonic stability of the two notes was melodically (i.e., contextually) defined, any changes in the discrimination of the signal are likely to have originated at the cognitive (perceptive) rather than physical (acoustic) level.

In connection with the effects of harmonic stability on pitch perception, it is also important to point out that the results of the main experiment showed significantly better pitch discrimination of the participants in unequal than equal harmonic stability conditions. This effect appears to be caused by a small difference between the magnitude of the effect of harmonic stability in the  $RT=CT$  trials with respect to the  $RT\neq CT$  trials. By looking at Figure 3.3 (which illustrates the interaction between *Harmonic Stability* and *Pitch*), it becomes evident that harmonic stability disturbs the perception of different pitches slightly more than the discrimination of equal notes (i.e., the difference between the subjects' discrimination of equal tones in equally with respect to unequally stable situations was smaller than the distance between the participants' discrimination of different pitches in unequally with respect to equally stable conditions). Note that the difference between the subjects' performance in equal and unequal

stability situations was very small, possibly due to the relatively large interacting effect of *Pitch* and *Harmonic Stability*.

Finally, a possible explanation for the observed results at the psychological level is that the relatively strong causal connection (e.g., “driving force” or “tonal attraction” generated by voice-leading motion) between adjacent components of a tonal harmonic progression minimizes the distance between the individual elements (tones) of those harmonies. Even when the tones are not contiguous pitches, their harmonic contexts are immediately and causally related. Following this, when the elements (pitches) are not a mere part of the context but, more specifically, a stable and defining member of the harmony (root, third or fifth of the chord), their [causal] connection is particularly smooth. As a consequence, two stable pitches are perceived as more similar (closer together) than two notes that differ in terms of harmonic stability.

## CHAPTER 4

### Supplementary Experiment

#### 4.1 Method.

##### 4.1.1 Procedure.

The procedure used in the supplementary experiment was the same as that employed in the main experiment, as described in Section 3.1.1.

##### 4.1.2 Stimuli.

An additional set of sixty stimuli in nonchanging harmonic context was created with the purpose of juxtaposing them to the examples from the main experiment (changing harmonic context). The visual component of the stimuli was exactly the same as that of the main experiment. The nonchanging-harmony examples, included in Appendix B, paralleled those of the main experiment in all possible respects, namely melodic pattern, keys, and pitch distance between RT and CT. In the  $RT \neq CT$  condition, the intervallic distance between RT and CT was invariably a second, matching the changing-harmony examples. Resembling the stimuli from the main experiment, the new samples kept the melodic/intervallic context of CT as consistent as possible with that of RT. As a result, the interval of approach of RT and CT had to be equal in the  $RT = CT$  condition and different by an interval of a second in the  $RT \neq CT$  condition. The nonchanging-harmony stimuli randomly represented all diatonic chords in mayor keys. The analysis of the supplementary experiment was based on data from a total of 120 stimuli: the sixty stimuli that corresponded to the main experiment (data was obtained from the main experiment) and the sixty nonchanging-harmony examples.

#### 4.1.3 Design.

In an attempt to partially compensate for the limitations of an experimental design that does not include nonchanging-harmony stimuli, this thesis proposes a supplementary experiment that compares changing-harmony with nonchanging-harmony situations.

The supplementary experiment was a between-subjects design with two factors. The main factor of interest, *Harmony*, had two levels:

- (1) Changing Harmony: The harmonic context of RT was different from that of CT. The sixty stimuli from the main experiment represented this condition.
- (2) Nonchanging Harmony: The harmonic context of RT was the same as that of CT. The additional set of sixty stimuli constituted this condition.

The second factor, *Pitch*, was comparable to the main factor of the main experiment. The design of the supplementary experiment was equivalent to the one shown in Table 2.1, with thirty stimuli per cell (120 musical examples in total, shown in Appendixes A and B).

#### 4.2 Results.

Figure 4.1 shows the percentage of correct responses for the supplementary stimuli only (60 nonchanging-harmony stimuli,  $n = 273$  nonmusicians, age 18-49) at the two levels of the *Pitch* factor ( $M_{(RT=CT)|nonchanging\_harmony} = 0.841$  ;  $M_{(RT \neq CT)|nonchanging\_harmony} = 0.708$ ). As discussed in Chapter 2, these results are very likely to be affected by confounds (especially number of different notes between RT and CT, intervallic context, and harmonic stability). In effect, and marking an essential difference with the main experiment, the subjects' better sensitivity for equal than different pitches was expected according to the effects of confounding factors.

Three different between-subjects analyses of variance were performed using *d-prime* as dependent variable and *Harmony* (changing vs. nonchanging) as factor. These analyses

combined data from the main [changing-harmony] stimuli with the supplementary [nonchanging-harmony] examples.

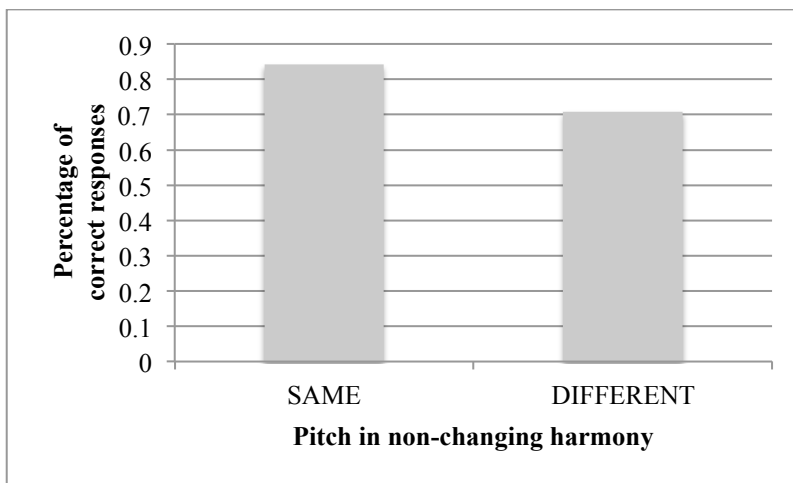


Figure 4.1 Discrimination of equal versus different notes in nonchanging harmony conditions.

The first ANOVA compared the total data set from the main experiment (data from 60 changing-harmony stimuli,  $n = 363$  nonmusicians) with the results of the supplementary addition (60 nonchanging-harmony trials,  $n = 273$  nonmusicians), revealing that pitch discrimination was significantly better in nonchanging harmonic contexts ( $M_{\text{nonchanging\_harmony}} = 1.999$  ;  $SD_{\text{nonchanging\_harmony}} = 1.411$ ) than in changing harmonic contexts ( $M_{\text{changing\_harmony}} = 0.761$  ;  $SD_{\text{changing\_harmony}} = 0.804$ ):  $F(1, 634) = 195.389$  ;  $p < 0.001$ ,  $\eta^2 = .235$  (see Figure 4.2).

This relatively large disruption of pitch discrimination in changing-harmony conditions with respect to nonchanging-harmony situations was expected, in great part, due to the effects of confounding factors (namely intervallic context, number of different notes between RT and CT, and harmonic stability, as explained in Chapter 2). Nevertheless, these results are relevant in that they provide an approximate idea of how the musical context that is most often created by



changing harmonies in a relatively consistent melodic setting affects pitch discrimination with respect to musical contexts that are harmonically and melodically static. In addition, these results confirm the hypothesis that the incorporation of a changing harmonic context affects pitch perception.

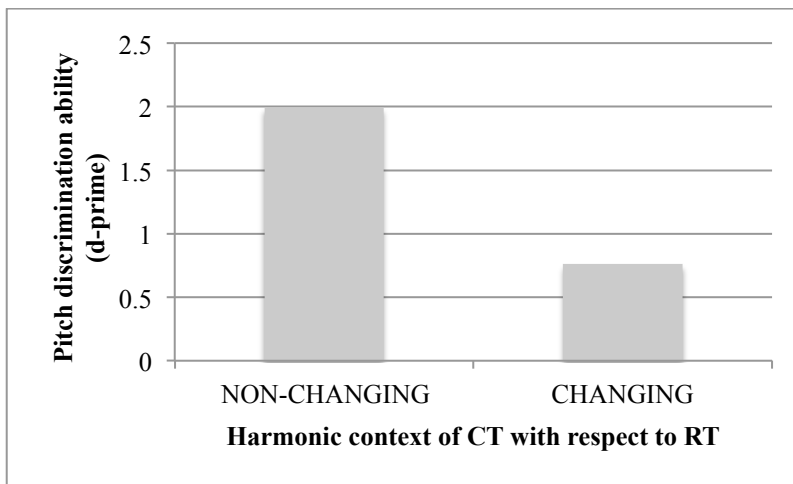


Figure 4.2 Pitch discrimination in nonchanging versus changing harmonic conditions.

With the purpose of reducing the confounding effects of intervallic context, a second between-subjects ANOVA compared the nonchanging-harmony condition (60 stimuli) with only those stimuli (16 stimuli) from the main experiment that paralleled the nonchanging-harmony examples in terms of intervallic context (i.e., changing-harmony stimuli with equal intervallic approach for RT and CT in the RT=CT condition and different intervallic approach in the RT≠CT situation). Once again, the participants' pitch discrimination was significantly better in nonchanging-harmony conditions (see descriptive statistics above) than in changing-harmony situations ( $M_{\text{changing\_harmony}} = 0.413$  ;  $SD_{\text{changing\_harmony}} = 1.03$ ):  $F(1,634) = 268.456$  ,  $p < 0.001$  ,  $\eta^2 = .297$  (see Figure 4.3). The larger effect size with respect to the first analysis does not

necessarily imply that, under equivalent intervallic settings, changing harmony interferes with pitch discrimination more than nonchanging harmony. Similarly, the decrease in  $d\text{-prime}_{\text{changing\_harmony}}$  is not likely to be due to the intervallic factor (in effect, an explanation of this decrease based on the intervallic characteristics of the stimuli would contradict previous literature without plausible justification<sup>20</sup>).

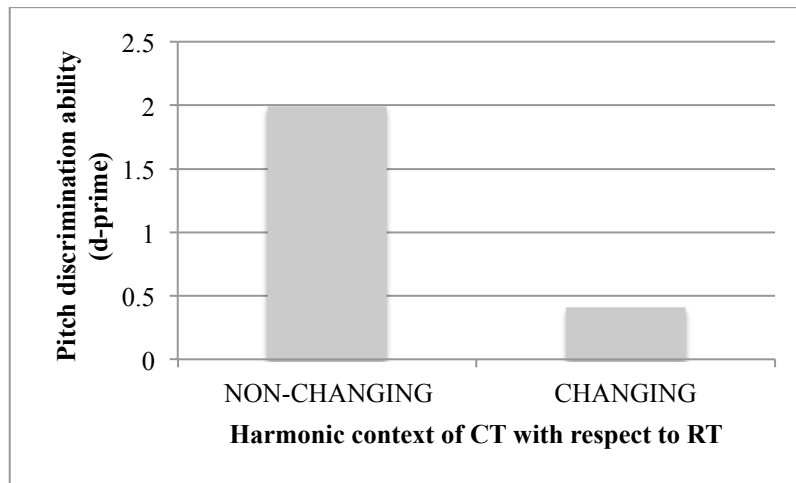


Figure 4.3 Pitch discrimination in nonchanging versus changing harmonic conditions, controlling for intervallic context.

As noted in Chapter 2, changing-harmony stimuli that paralleled nonchanging-harmony examples in terms of intervallic context, differed with respect to harmonic stability. All changing-harmony stimuli in the  $RT=CT$  condition corresponded to unequal harmonic stability, whereas those in the  $RT \neq CT$  condition corresponded to equal harmonic stability. The reverse occurred with the nonchanging-harmony examples. Consistently with the results from the main

<sup>20</sup> The supplementary experiment in this thesis does not control for confounds in a way that would allow us to conclude about the effects of intervallic context. Furthermore, the first ANOVA, which is here being compared with the second one, contained examples of varied intervallic contexts (not only opposite intervallic situations with respect to the second ANOVA).

experiment, it seems reasonable to propose that the decrease in *d-prime* and consequential increase in effect size being discussed here are likely to be due to the interaction between *Pitch* and *Harmonic Stability* (see Figure 3.3).

Lastly, with the purpose to illuminate the effects of harmony under controlled harmonic-stability situations, the third ANOVA compared the nonchanging-harmony condition (60 stimuli) with only those stimuli (30) from the main experiment that paralleled the added examples in terms of harmonic stability (i.e., changing-harmony stimuli with equal harmonic stability for RT and CT in the RT=CT condition and different harmonic stability in the RT≠CT situation). A significant effect of *Pitch* was observed ( $M_{\text{changing\_harmony}} = 1.11$  ,  $SD_{\text{changing\_harmony}} = 1.013$ ):  $F(1,634) = 84.951$  ,  $p < 0.001$  ,  $\eta^2 = .118$  (see Figure 4.4).

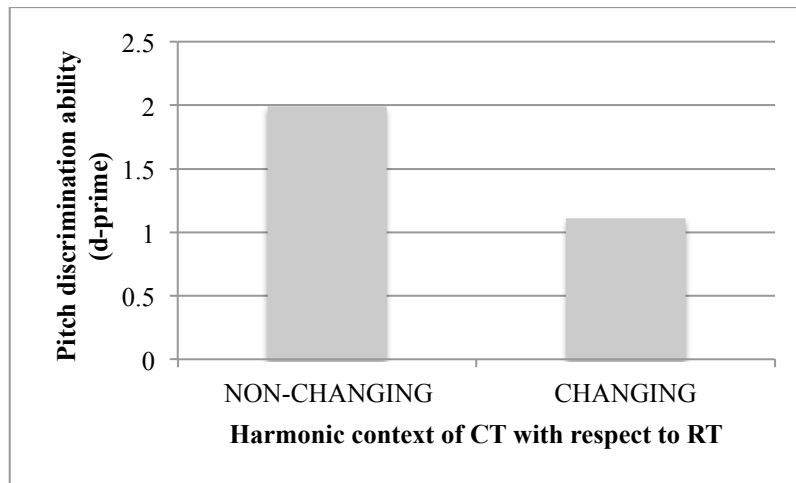


Figure 4.4 Pitch discrimination in nonchanging versus changing harmonic conditions, controlling for harmonic stability.

As discussed in Chapter 2, the stimuli being compared in this third analysis are dissimilar in terms of intervallic context (changing-harmony examples with equal stability for equal RT and CT corresponded to stimuli with different intervals of approach for CT and RT, marking a

crucial difference with nonchanging-harmony situations). It is important to point out here that this final analysis revealed improved discrimination abilities<sup>21</sup> in changing-harmony conditions with respect to the previous two (and therefore smaller effect size because the mean of the nonchanging-harmony condition is the same for all the ANOVAs). Intervallic context, the unbalanced confounding factor in the third analysis, cannot be responsible for this improvement. If anything, the intervallic setting should be responsible for decreased rather than increased discrimination abilities, suggesting that harmonic context is likely to affect pitch discrimination.

### 4.3 Discussion.

To begin with, it is essential to consider that the results of the supplementary experiment cannot be conclusive on their own because they are likely to be contaminated by the effects of factors that could not be controlled (as discussed in Chapter 2). Nevertheless, they illuminate the study of pitch perception in changing harmony by confirming the findings of the main experiment, and by analyzing the effects of changing and nonchanging harmonic contexts as they are likely to occur in relatively constant melodic settings. Based on traditional techniques (i.e., the statistical comparison of changing- versus nonchanging-harmony conditions), the results of the supplementary experiment support the findings obtained with a more unconventional procedure (main experiment).

In general, the outcomes of the supplementary experiment provide support for better pitch discrimination under nonchanging with respect to changing harmonic contexts in relatively common musical situations. This finding reinforces the hypothesis that moving harmony affects pitch perception, suggested by the results of the main experiment. Notice, however, that, due to the effects of confounds, an examination of the perception of equal versus different pitches (like

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<sup>21</sup> The *d-prime*<sub>changing\_harmony</sub> obtained in the third analysis is larger than the previous two.

the first analysis of the main experiment) would be futile. In addition, the results of the second experiment provide support for the hypothesis, proposed by the main experiment, that harmony shapes the cognitive representation of musical notes by defining their stability. In effect, a comparison of the second and third ANOVAs of the supplementary experiment suggests that harmonic stability influences pitch perception, and, moreover, that the effects of harmonic stability might be larger than those of intervallic context (i.e., controlling for intervallic context but not for harmonic stability led to a smaller  $d'$  than controlling for harmonic stability but not for intervallic context –see Section 4.2). Further studies designed to specifically analyze the impact of both harmonic and intervallic context on pitch discrimination should be relevant in this respect.

Overall, the results of the two experiments combined together confirm previous findings that pitch discrimination is, at least in part, contextually shaped: the participants' ability to discriminate same/different pitches during the experimental trials was greatly disrupted with respect to their ability to discriminate same/different notes under nonnoisy conditions (only those subjects who scored 100% correct in the qualification test, which presented same/different pitches in noncontextual settings, completed the experimental trials). Any attempts to interpret the results of the supplementary experiment further would be in vain, because it is impossible to be certain about which factors are responsible for the observed differences in pitch discrimination.

## CHAPTER 5

### General Discussion

#### 5.1 Theoretical Significance.

Pitch is an essential aspect of tonal music. It is precisely pitch organization and hierarchization that define tonality. Harmony and melody are pitch combinations in which the ordered connections between the elements are more important than the components themselves. For instance, the harmonic progression V-I conveys a sense of closure whereas its reverse, I-V, suggests suspension; similarly, the melodic lines  $^4^3^2^1$  and  $^1^2^3^4$  create different expectations. The internal organization (order) of the melodic and harmonic aspects of pitch composes the fundamental generative source of motion in tonal music. The disposition of the harmonic and melodic elements engenders the causal relationships that constitute the base of tonal music's "intuitive logic." It seems thus reasonable to propose that pitch representation in the brain should be, at least in part, contextually (i.e., relationally) rather than intrinsically (i.e., inherently) shaped. In effect, it has been well established in the field of music cognition that the perception of acoustic signals, including musical pitches, is highly dependent on the context (Plack, 2005).

Following this idea, this thesis has aimed to contribute to our understanding of the effects of changing harmonic context on pitch perception. It provided evidence that harmonic context and stability shape the cognitive representation of musical tones. Specifically, the results of this study have shown greater disruption in discrimination abilities for different than for identical notes in changing-harmony conditions; slightly better pitch sensitivity in unequal than equal harmonic stability situations; and increased perception abilities for unequally, with respect to equally, stable notes that differ in pitch, but the opposite effect for equal tones. Furthermore, this

thesis has provided support for better pitch discrimination under nonchanging with respect to changing harmonic contexts in relatively common musical situations. Altogether, these findings suggest, at the psychological level, that conventional harmonic progressions tend to bring together the percepts of musical notes that are introduced in adjacent chordal functions, particularly when the tones are stable (consonant) members of their contextual harmony.

Beyond the statistically significant results, this thesis is relevant in three respects. First, it illuminates current models of pitch representation through the analysis of the perceptual mechanisms involved in the interaction of pitch and harmony, an area that has not received substantial experimental investigation. Whereas numerous theoretical, behavioral, and scientific studies have examined aspects of pitch and harmony perception, the empirical research focusing on the relationships between pitch and harmony at the cognitive level is noticeably scarce. Second, this thesis proposes an innovative methodological approach that allows for minimization of confounds in the examination of contextual aspects of music that cannot be manipulated independently from other musical features. Finally, this study emphasizes the experimental difficulties and consequential problems of interpretation implied in the research of contextual aspects of music, an issue often disregarded by previous investigations.

## **5.2 Future Directions.**

It is hoped that the results of this study and the original methodology employed will motivate further experimental research on the relationships between harmony and pitch perception. Related topics could include the investigation of pitch perception in modulating harmonic contexts (e.g., a study based on stimuli in which RT and CT are presented in different key contexts), nonadjacent changing harmonies (e.g., an empirical examination using musical passages that incorporate additional harmonic changes between the harmony of RT and that of

CT), and harmonic contexts presented chordally rather than melodically. In addition, In addition, studies that incorporate other intervallic distances (i.e., larger than a second) between RT and CT should illuminate the topic in question. Concerning this, it is important to note that the pilot survey of this thesis contained one example in which the distance between RT and CT was a third, and the participants tended to judge the two pitches as equal. Finally, as noted in Section 4.3, the results of the second and third ANOVAs of the supplementary experiment suggested that the effects of harmonic stability on pitch discrimination might be larger than those of intervallic context. Research oriented to analyze the impact of both harmonic and intervallic context on pitch perception should provide relevant information concerning this issue.



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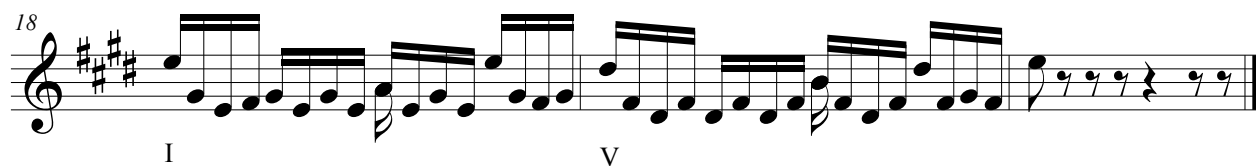
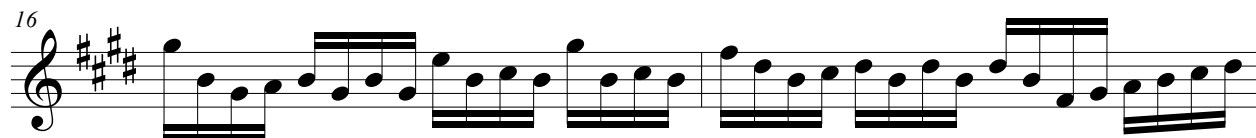
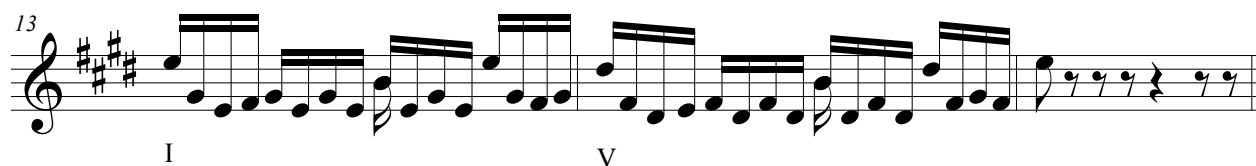
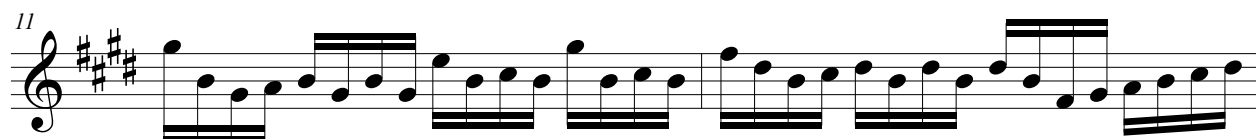
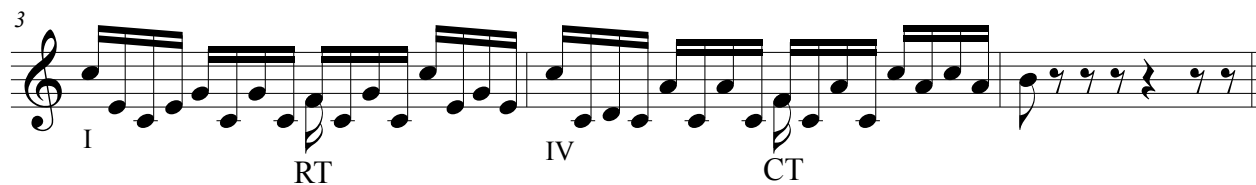
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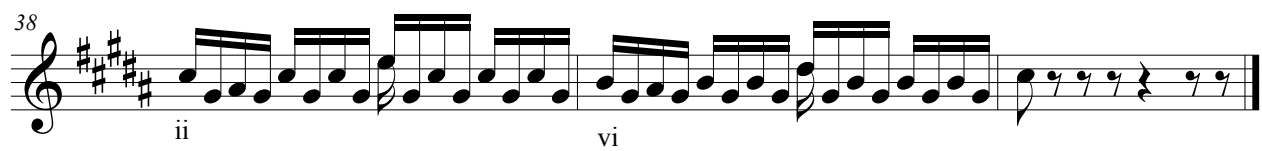
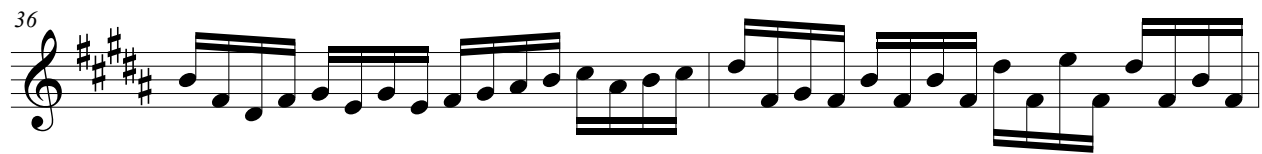
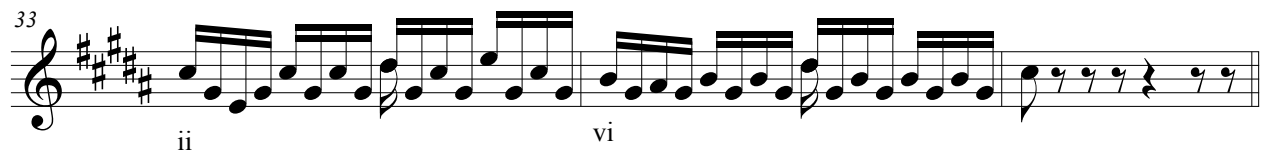
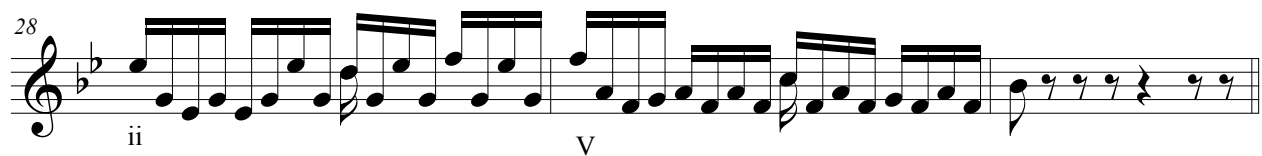
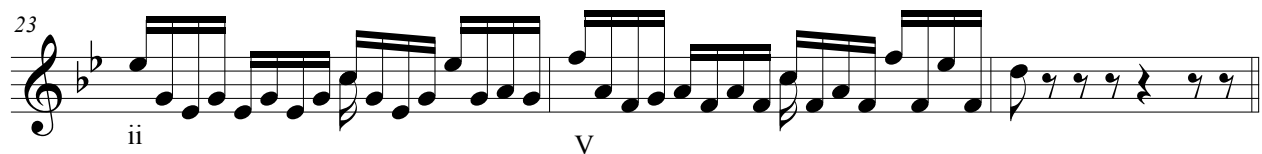
# APPENDIX A

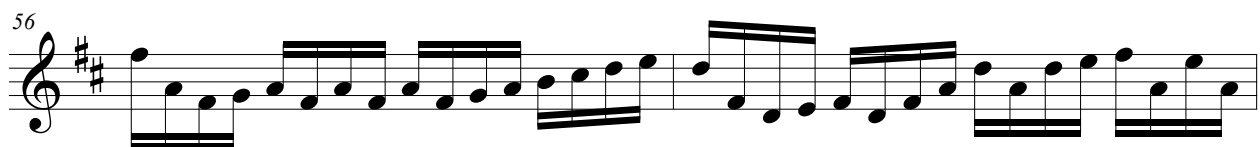
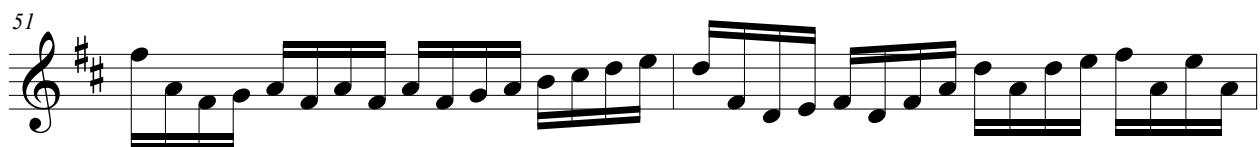
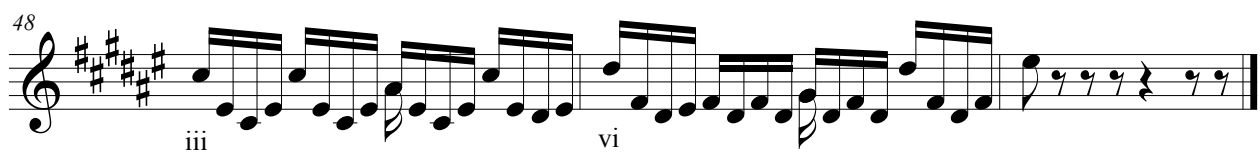
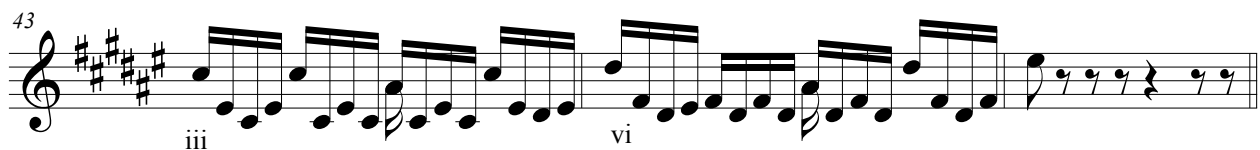
## Changing-harmony Stimuli

### Pattern 1


♩ = 82







61

63 


66

68

IV V

This musical notation shows measures 68 through 71 of the song 'The Rose Tree'. The key signature is three sharps (F#, C#, G#). The melody is written on a single staff. Measure 68 starts with a treble clef and a key signature change to three sharps. The melody consists of eighth and sixteenth notes. Measure 69 contains a double bar line and the Roman numeral 'IV' below it. Measure 70 contains a double bar line and the Roman numeral 'V' below it. Measure 71 ends with a double bar line and a repeat sign. The lyrics 'The Rose Tree' are written below the staff.

71



73

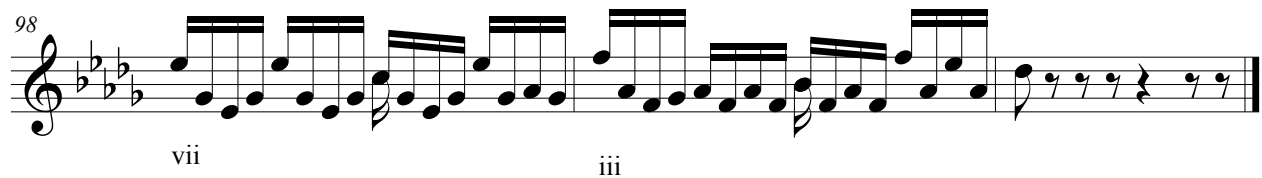
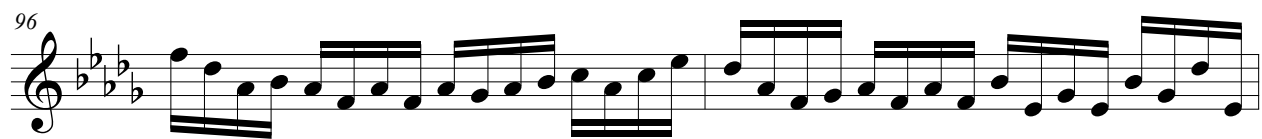
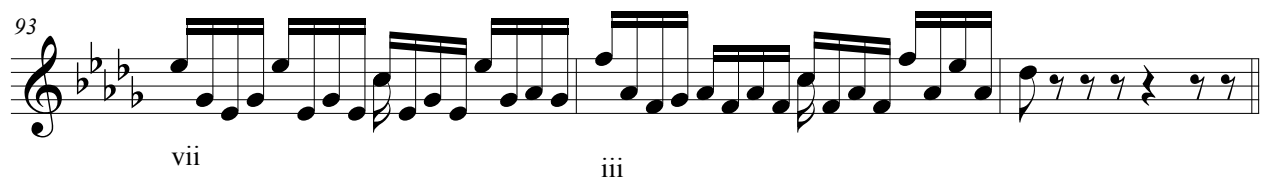
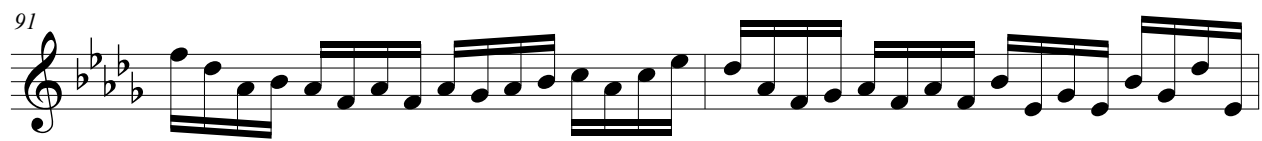
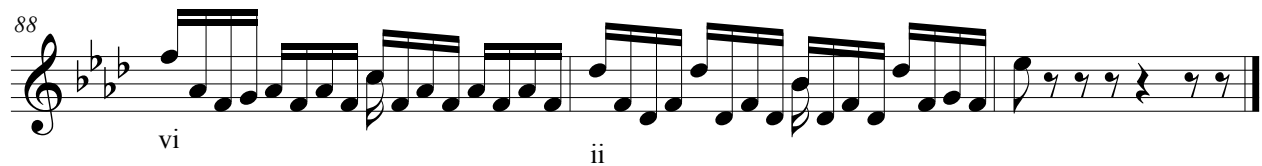
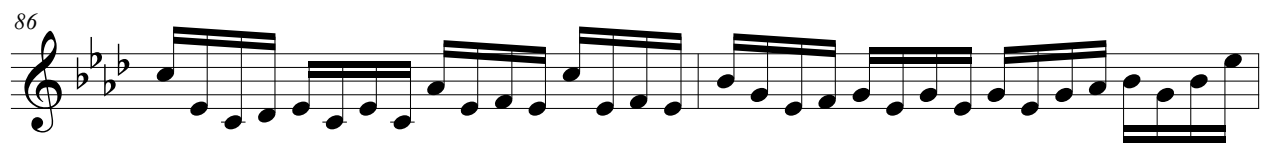
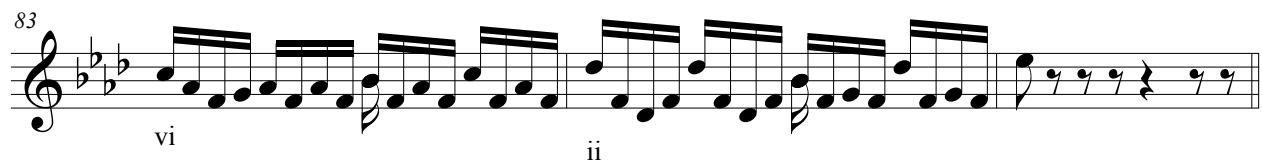
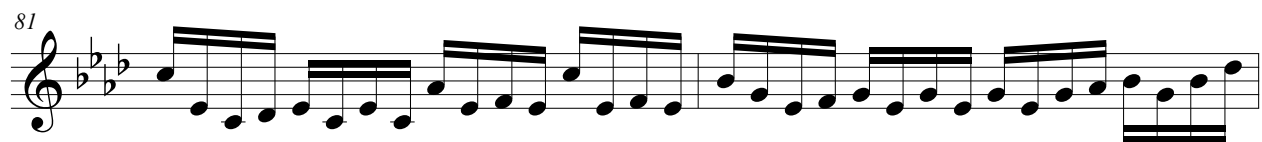
V I

76

Measure 76: Treble clef, key signature of two flats (Bb and Eb). The melody consists of eighth and sixteenth notes, with some beamed sixteenth notes. The rhythm is complex, with various note values and rests.

78

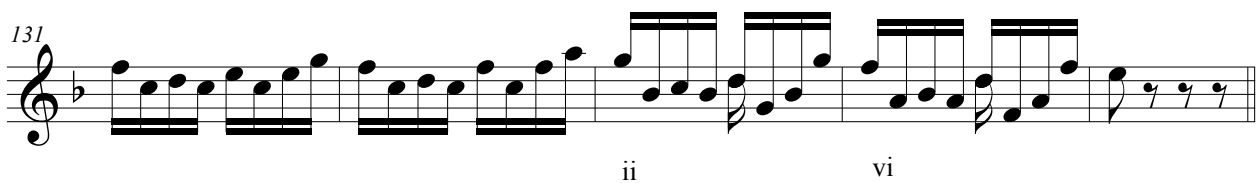
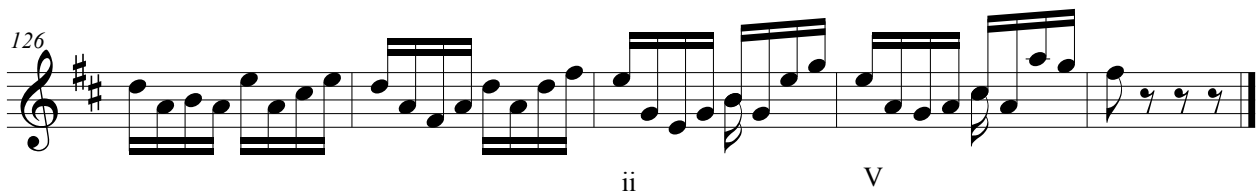
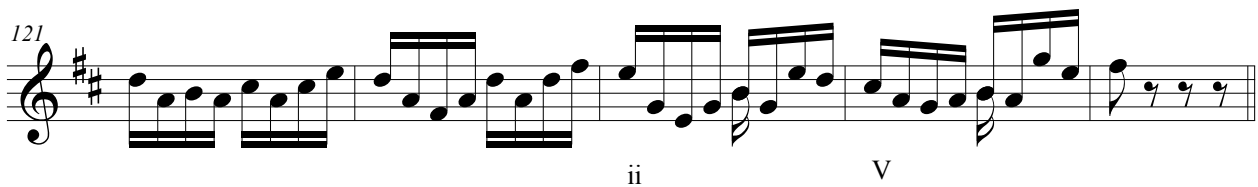
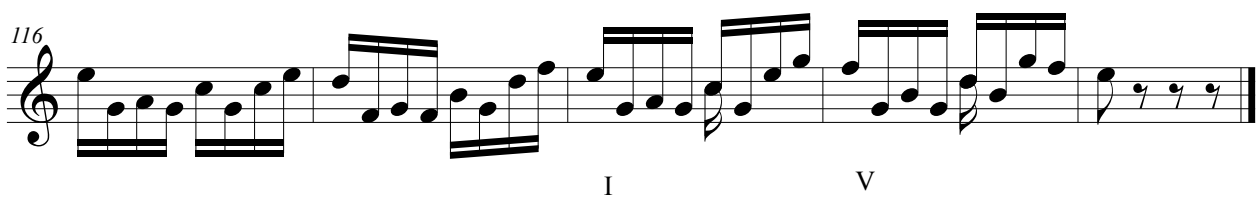
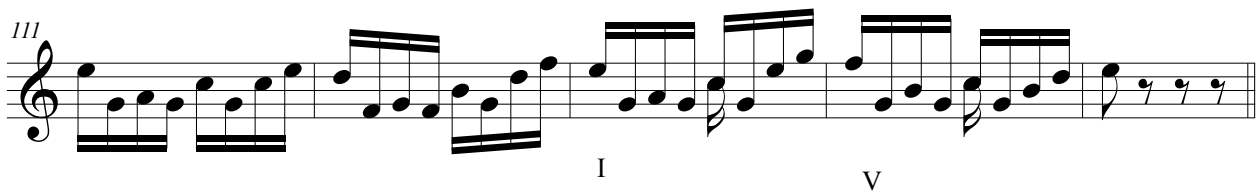
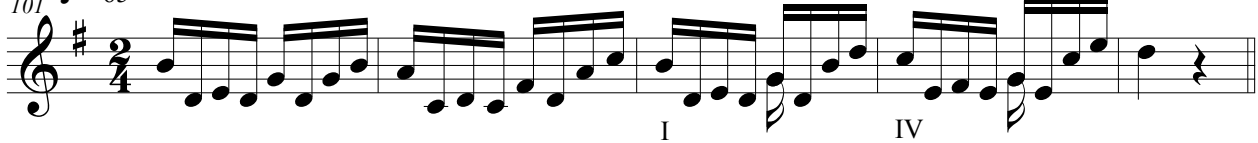
V I





# Pattern 2

101  $\text{♩} = 65$



136

ii vi

141

iii vi

146

iii vi

151

IV I

156

IV I

161

IV V

166

IV V

171

V I

176

V I

181

vi ii

186

vi ii

191

vii iii

196

vii iii

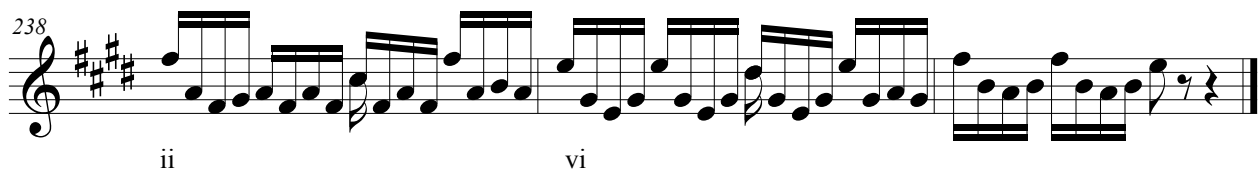
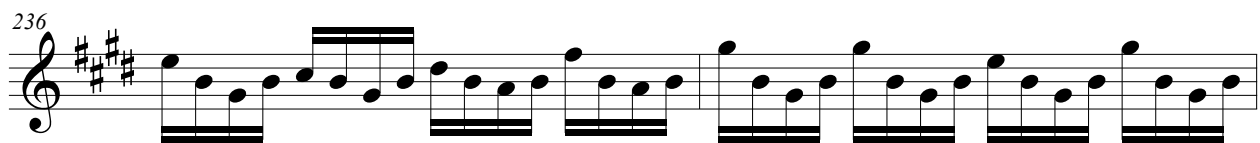
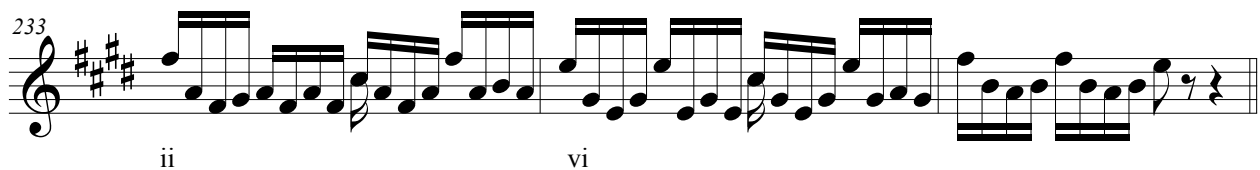
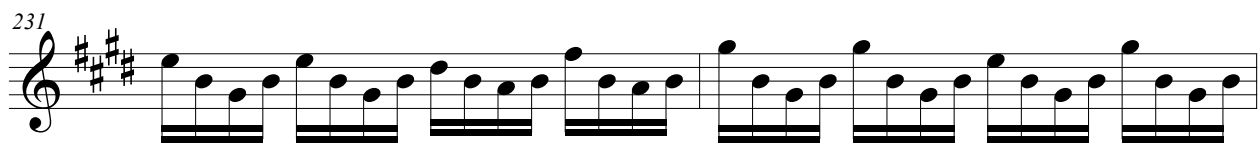
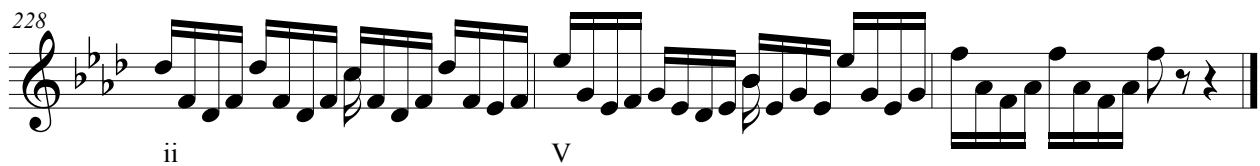
### Pattern 3

201 ♩ = 97

203

I IV





246



Musical notation for exercise 246, featuring a treble clef, a key signature of one flat (B-flat), and a melody line with various note values and rests.

[illegible][illegible]


253

IV I

256


Measure 256: Treble clef. The melody consists of eighth and sixteenth notes, with some beamed sixteenth notes. The notes are: G4, A4, B4, C5, B4, A4, G4, F#4, E4, D4, C4, B3, A3, G3, F#3, E3, D3, C3, B2, A2, G2, F#2, E2, D2, C2, B1, A1, G1, F#1, E1, D1, C1, B0, A0, G0, F#0, E0, D0, C0, B-1, A-1, G-1, F#-1, E-1, D-1, C-1, B-2, A-2, G-2, F#-2, E-2, D-2, C-2, B-3, A-3, G-3, F#-3, E-3, D-3, C-3, B-4, A-4, G-4, F#-4, E-4, D-4, C-4, B-5, A-5, G-5, F#-5, E-5, D-5, C-5, B-6, A-6, G-6, F#-6, E-6, D-6, C-6, B-7, A-7, G-7, F#-7, E-7, D-7, C-7, B-8, A-8, G-8, F#-8, E-8, D-8, C-8, B-9, A-9, G-9, F#-9, E-9, D-9, C-9, B-10, A-10, G-10, F#-10, E-10, D-10, C-10, B-11, A-11, G-11, F#-11, E-11, D-11, C-11, B-12, A-12, G-12, F#-12, E-12, D-12, C-12, B-13, A-13, G-13, F#-13, E-13, D-13, C-13, B-14, A-14, G-14, F#-14, E-14, D-14, C-14, B-15, A-15, G-15, F#-15, E-15, D-15, C-15, B-16, A-16, G-16, F#-16, E-16, D-16, C-16, B-17, A-17, G-17, F#-17, E-17, D-17, C-17, B-18, A-18, G-18, F#-18, E-18, D-18, C-18, B-19, A-19, G-19, F#-19, E-19, D-19, C-19, B-20, A-20, G-20, F#-20, E-20, D-20, C-20, B-21, A-21, G-21, F#-21, E-21, D-21, C-21, B-22, A-22, G-22, F#-22, E-22, D-22, C-22, B-23, A-23, G-23, F#-23, E-23, D-23, C-23, B-24, A-24, G-24, F#-24, E-24, D-24, C-24, B-25, A-25, G-25, F#-25, E-25, D-25, C-25, B-26, A-26, G-26, F#-26, E-26, D-26, C-26, B-27, A-27, G-27, F#-27, E-27, D-27, C-27, B-28, A-28, G-28, F#-28, E-28, D-28, C-28, B-29, A-29, G-29, F#-29, E-29, D-29, C-29, B-30, A-30, G-30, F#-30, E-30, D-30, C-30, B-31, A-31, G-31, F#-31, E-31, D-31, C-31, B-32, A-32, G-32, F#-32, E-32, D-32, C-32, B-33, A-33, G-33, F#-33, E-33, D-33, C-33, B-34, A-34, G-34, F#-34, E-34, D-34, C-34, B-35, A-35, G-35, F#-35, E-35, D-35, C-35, B-36, A-36, G-36, F#-36, E-36, D-36, C-36, B-37, A-37, G-37, F#-37, E-37, D-37, C-37, B-38, A-38, G-38, F#-38, E-38, D-38, C-38, B-39, A-39, G-39, F#-39, E-39, D-39, C-39, B-40, A-40, G-40, F#-40, E-40, D-40, C-40, B-41, A-41, G-41, F#-41, E-41, D-41, C-41, B-42, A-42, G-42, F#-42, E-42, D-42, C-42, B-43, A-43, G-43, F#-43, E-43, D-43, C-43, B-44, A-44, G-44, F#-44, E-44, D-44, C-44, B-45, A-45, G-45, F#-45, E-45, D-45, C-45, B-46, A-46, G-46, F#-46, E-46, D-46, C-46, B-47, A-47, G-47, F#-47, E-47, D-47, C-47, B-48, A-48, G-48, F#-48, E-48, D-48, C-48, B-49, A-49, G-49, F#-49, E-49, D-49, C-49, B-50, A-50, G-50, F#-50, E-50, D-50, C-50, B-51, A-51, G-51, F#-51, E-51, D-51, C-51, B-52, A-52, G-52, F#-52, E-52, D-52, C-52, B-53, A-53, G-53, F#-53, E-53, D-53, C-53, B-54, A-54, G-54, F#-54, E-54, D-54, C-54, B-55, A-55, G-55, F#-55, E-55, D-55, C-55, B-56, A-56, G-56, F#-56, E-56, D-56, C-56, B-57, A-57, G-57, F#-57, E-57, D-57, C-57, B-58, A-58, G-58, F#-58, E-58, D-58, C-58, B-59, A-59, G-59, F#-59, E-59, D-59, C-59, B-60, A-60, G-60, F#-60, E-60, D-60, C-60, B-61, A-61, G-61, F#-61, E-61, D-61, C-61, B-62, A-62, G-62, F#-62, E-62, D-62, C-62, B-63, A-63, G-63, F#-63, E-63, D-63, C-63, B-64, A-64, G-64, F#-64, E-64, D-64, C-64, B-65, A-65, G-65, F#-65, E-65, D-65, C-65, B-66, A-66, G-66, F#-66, E-66, D-66, C-66, B-67, A-67, G-67, F#-67, E-67, D-67, C-67, B-68, A-68, G-68, F#-68, E-68, D-68, C-68, B-69, A-69, G-69, F#-69, E-69, D-69, C-69, B-70, A-70, G-70, F#-70, E-70, D-70, C-70, B-71, A-71, G-71, F#-71, E-71, D-71, C-71, B-72, A-72, G-72, F#-72, E-72, D-72, C-72, B-73, A-73, G-73, F#-73, E-73, D-73, C-73, B-74, A-74, G-74, F#-74, E-74, D-74, C-74, B-75, A-75, G-75, F#-75, E-75, D-75, C-75, B-76, A-76, G-76, F#-76, E-76, D-76, C-76, B-77, A-77, G-77, F#-77, E-77, D-77, C-77, B-78, A-78, G-78, F#-78, E-78, D-78, C-78, B-79, A-79, G-79, F#-79, E-79, D-79, C-79, B-80, A-80, G-80, F#-80, E-80, D-80, C-80, B-81, A-81, G-81, F#-81, E-81, D-81, C-81, B-82, A-82, G-82, F#-82, E-82, D-82, C-82, B-83, A-83, G-83, F#-83, E-83, D-83, C-83, B-84, A-84, G-84, F#-84, E-84, D-84, C-84, B-85, A-85, G-85, F#-85, E-85, D-85, C-85, B-86, A-86, G-86, F#-86, E-86, D-86, C-86, B-87, A-87, G-87, F#-87, E-87, D-87, C-87, B-88, A-88, G-88, F#-88, E-88, D-88, C-88, B-89, A-89, G-89, F#-89, E-89, D-89, C-89, B-90, A-90, G-90, F#-90, E-90, D-90, C-90, B-91, A-91, G-91, F#-91, E-91, D-91, C-91, B-92, A-92, G-92, F#-92, E-92, D-92, C-92, B-93, A-93, G-93, F#-93, E-93, D-93, C-93, B-94, A-94, G-94, F#-94, E-94, D-94, C-94, B-95, A-95, G-95, F#-95, E-95, D-95, C-95, B-96, A-96, G-96, F#-96, E-96, D-96, C-96, B-97, A-97, G-97, F#-97, E-97, D-97, C-97, B-98, A-98, G-98, F#-98, E-98, D-98, C-98, B-99, A-99, G-99, F#-99, E-99, D-99, C-99, B-100, A-100, G-100, F#-100, E-100, D-100, C-100, B-101, A-101, G-101, F#-101, E-101, D-101, C-101, B-102, A-102, G-102, F#-102, E-102, D-102, C-102, B-103, A-103, G-103, F#-103, E-103, D-103, C-103, B-104, A-104, G-104, F#-104, E-104, D-104, C-104, B-105, A-105, G-105, F#-105, E-105, D-105, C-105, B-106, A-106, G-106, F#-106, E-106, D-106, C-106, B-107, A-107, G-107, F#-107, E-107, D-107, C-107, B-108, A-108, G-108, F#-108, E-108, D-108, C-108, B-109, A-109, G

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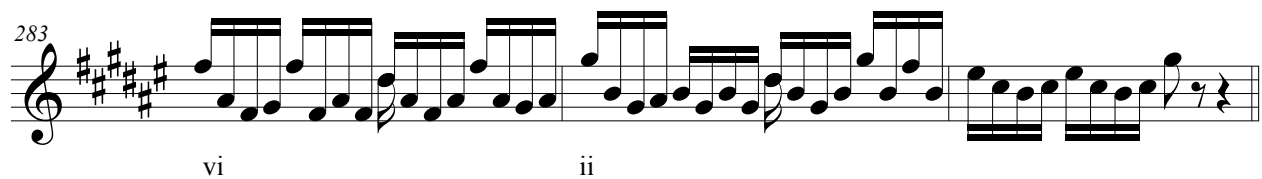
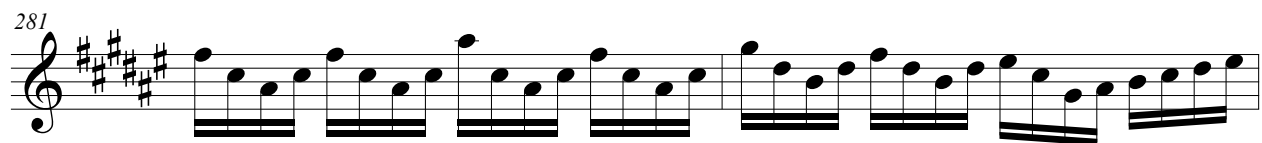
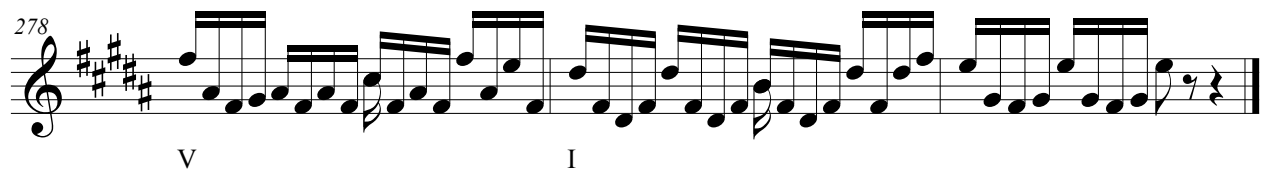
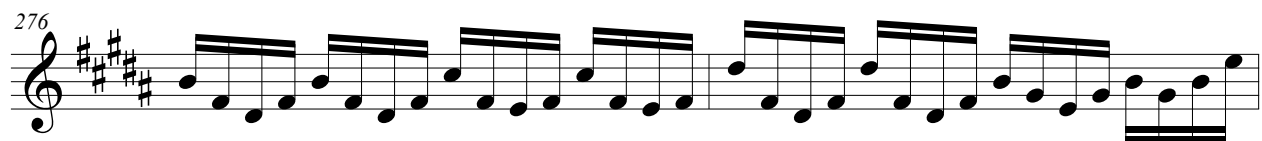
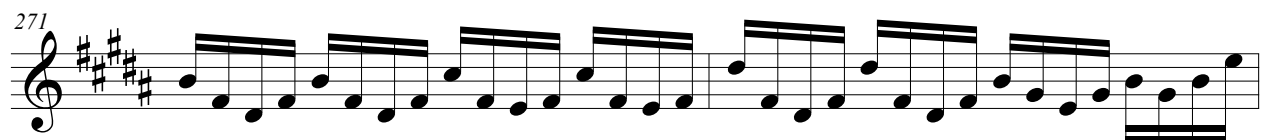
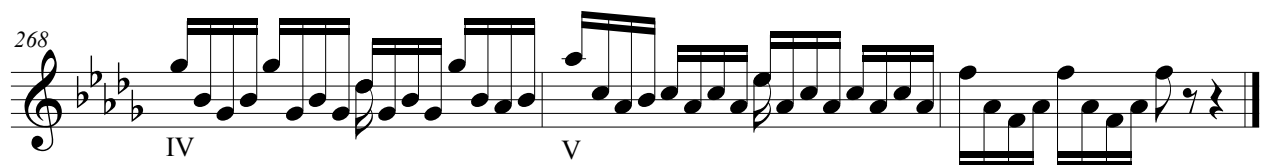
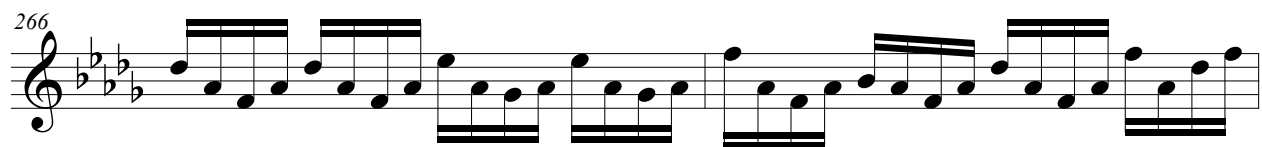
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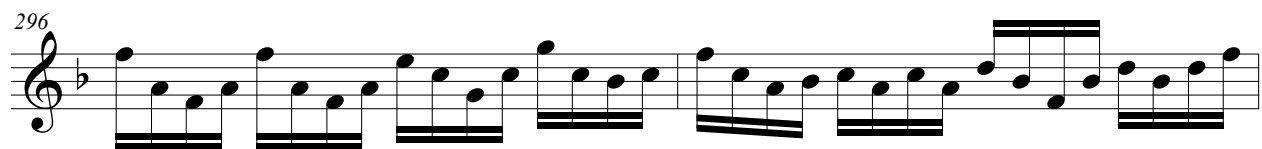
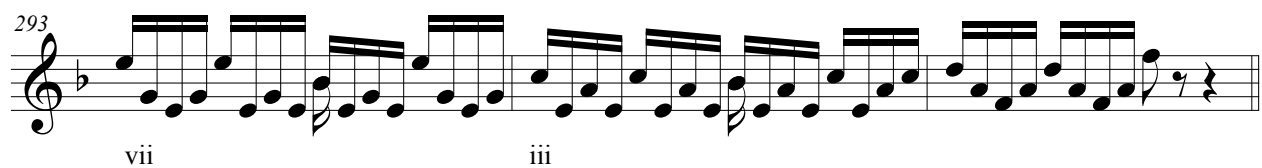
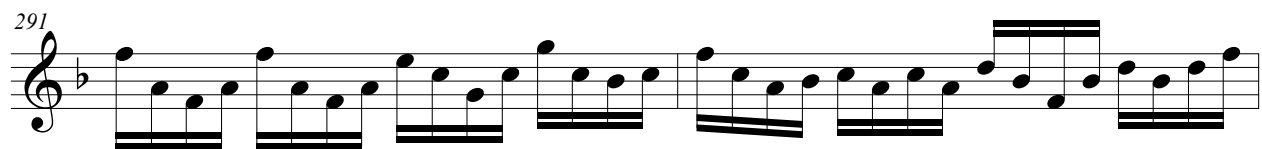
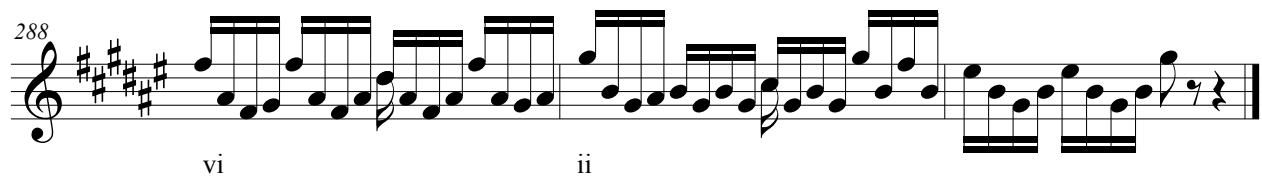
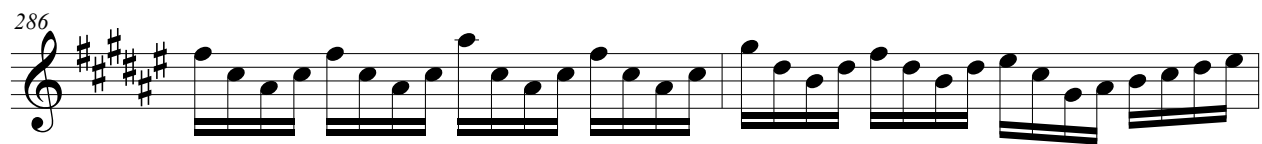
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263

IV V








### Nonchanging-harmony Stimuli

### Pattern 1

♩ = 82

The first system of the musical score is written on a single staff in 4/4 time. The tempo is marked as  $\text{♩} = 82$ . The melody consists of eighth and sixteenth notes, with some measures containing beamed sixteenth notes. The key signature has one flat (B-flat).

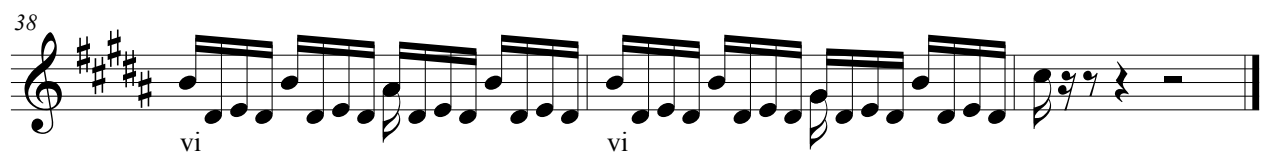
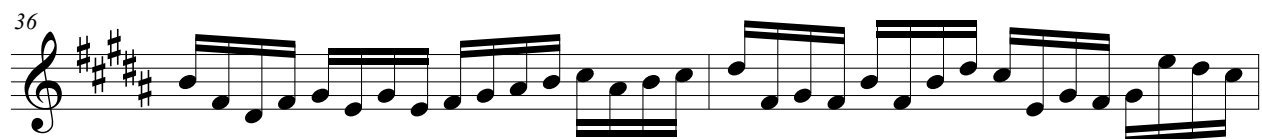
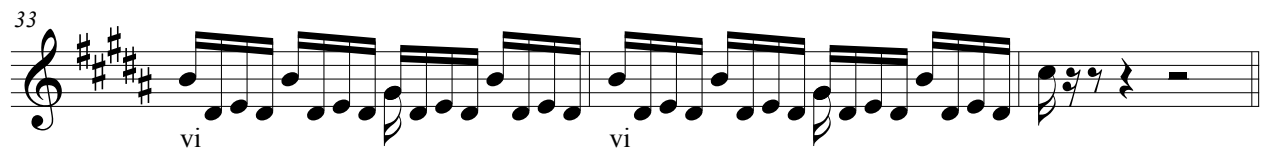
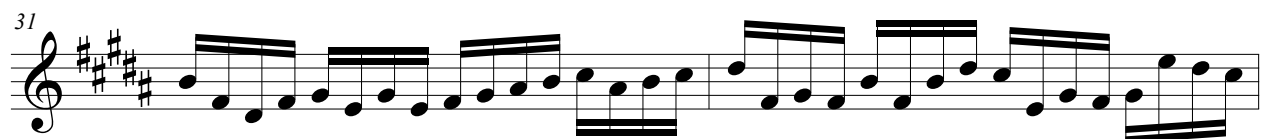
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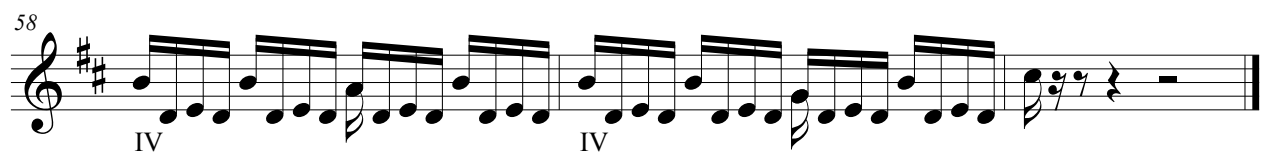
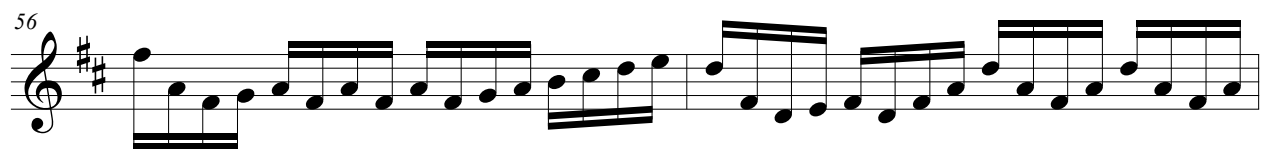
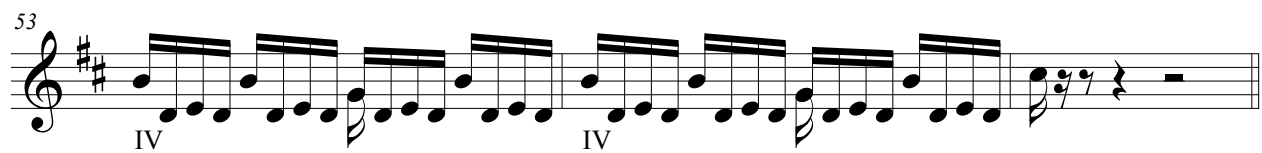
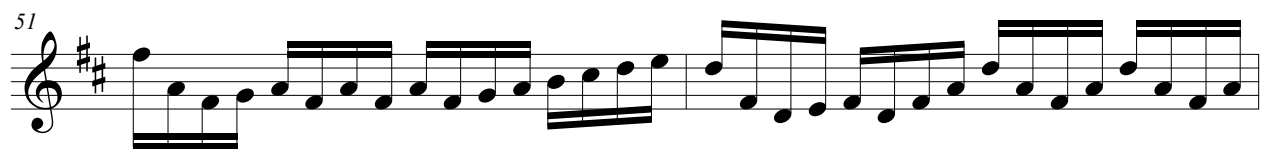
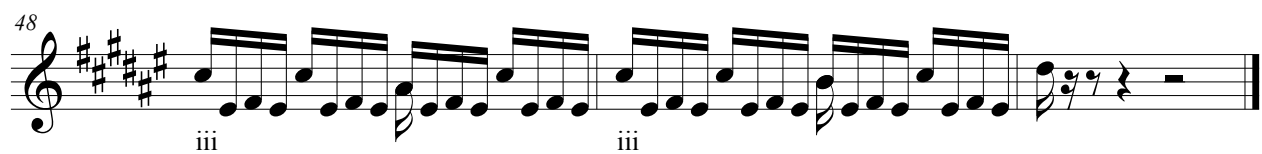
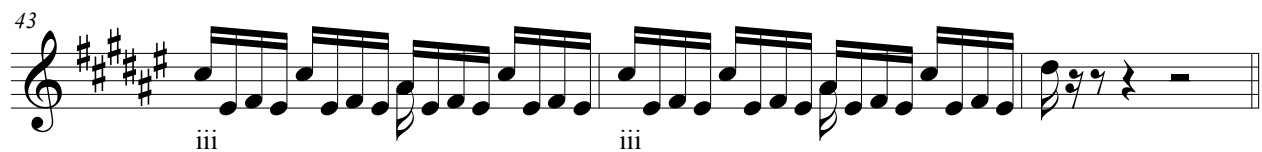
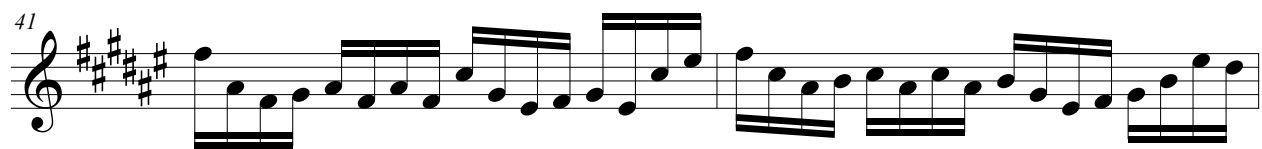
16

Measure 16: Treble clef, key signature of three sharps (F#, C#, G#). The melody consists of eighth and sixteenth notes, starting on G4 and ending on G4.

18

V V





61

Measure 61: Treble clef, key signature of three sharps (F#, C#, G#). The melody consists of eighth and sixteenth notes, starting on G#4 and moving in a generally ascending pattern with some chromaticism.

63

iii iii


66

Musical notation for measure 66. The staff is in treble clef with a key signature of three sharps (F#, C#, G#). The melody consists of eighth and sixteenth notes, with some beamed sixteenth notes. The bass line consists of eighth notes.

68

Musical notation for measures 68-71. The key signature is three sharps (F#, C#, G#). The melody is written on a treble clef staff. Measure 68 starts with a treble clef and a key signature change to three sharps. The melody consists of eighth and sixteenth notes. Measure 69 continues the melody. Measure 70 ends with a double bar line. Measure 71 is a whole rest.

71



73

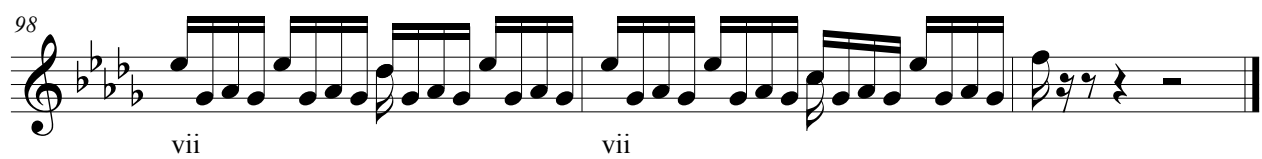
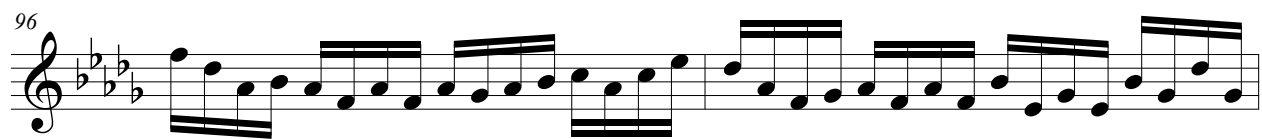
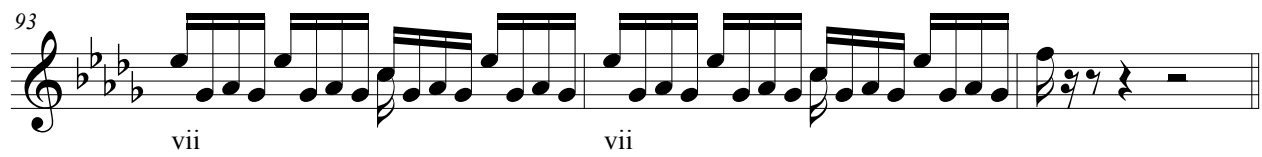
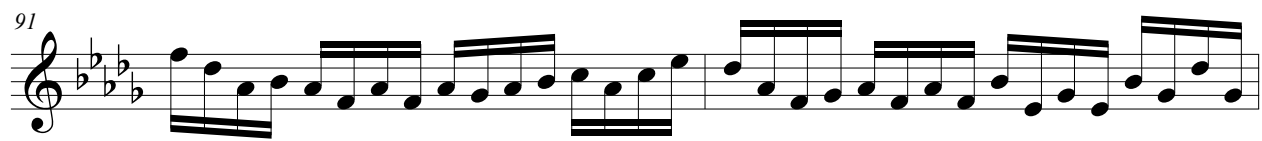
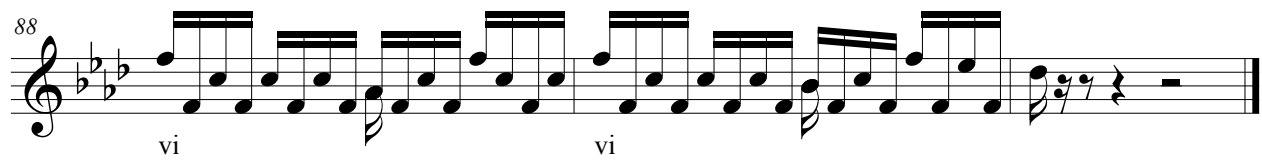
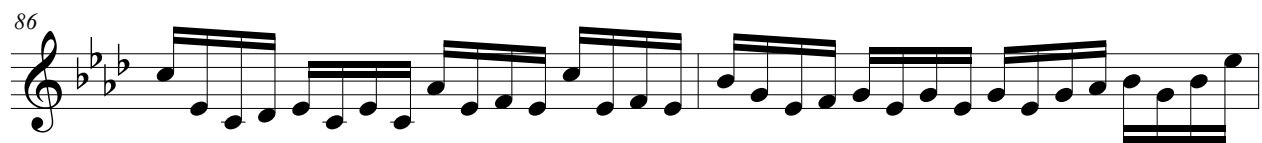
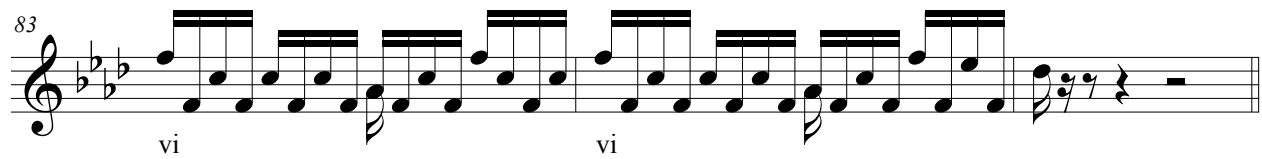
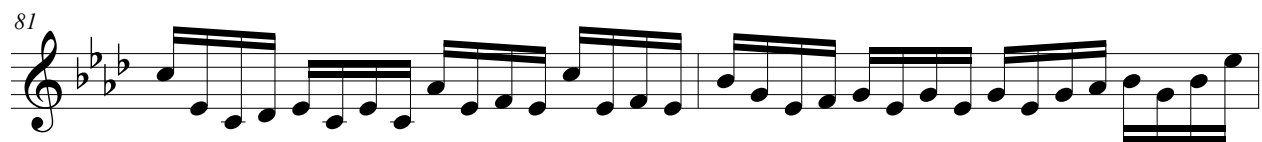
v v

76

Measure 76: Treble clef, key signature of two flats (Bb and Eb). The melody consists of a series of beamed eighth and sixteenth notes, creating a fast, flowing line. The notes start on G4, move up to A4, Bb4, and C5, then descend through Bb4, A4, G4, F4, E4, D4, C4, and Bb3, ending on A3.

78

v v



## Pattern 2

101  $\text{♩} = 65$

106

111

116

121

126

131

136

I I

I I

I I

I I

ii ii

ii ii

ii ii

ii ii

141

iii iii

146

iii iii

151

IV IV

156

IV IV

161

IV IV

166

IV IV

171

V V

176

V V

181

vi vi

186

vi vi

191

vii vii

196

vii vii

### Pattern 3

201 ♩ = 97

203

I I

206



